Detroit Diesel Engines

8.2 Liter Service Manual

Detroit Diesel Allison

6SE421 (Rev. 8/85)

Service Manual

8.2 LITER ENGINE

Detroit Diesel Allison
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NOTE:
Additional copies of this service manual may be purchased from Detroit Diesel Allison Distributors. See your yellow pages—under Engines, Diesel.

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FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the new Fuel Pincher Detroit Diesel Engine.

Full benefit of the long life and dependability built into these engines can be realized through proper operation and maintenance. Of equal importance is the use of proper procedures during engine overhaul.

Personnel responsible for engine operation and maintenance should study the sections of the manual pertaining to their particular duties. Similarly, before beginning a repair or overhaul job, the serviceman should read the manual carefully to familiarize himself with the parts or sub-assemblies of the engine with which he will be concerned.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. This publication is revised and reprinted periodically. It is recommended that users contact an authorized *Detroit Diesel Allison Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

CAUTION

The Fuel Pincher Engines contain many parts dimensioned in the metric system as well as in the customary system. Many fasteners are metric and are very close in dimension to familiar customary fasteners in the inch system. It is important to note that, during any maintenance procedures, replacement fasteners must have the same measurements and strength as those removed, whether metric or customary. (Numbers on the heads of metric bolts and on surfaces of metric nuts indicate their strength. Customary bolts use radial lines for this purpose, while most customary nuts do not have strength markings). Mismatched or incorrect fasteners can result in engine damage or malfunction or possibly personal injury, therefore, fasteners removed from the engine should be saved for re-use in the same locations whenever possible. Where the fasteners are not satisfactory for re-use, care should be taken to select a replacement that matches the original. For information and assistance, see your Detroit Diesel Allison Service Outlet.

IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of all motor vehicles. The service procedures recommended by Detroit Diesel Allison and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tools should be used when and as recommended.

It is important to note that some warnings against the use of specific service methods that can damage the vehicle or render it unsafe are stated in this service manual. It is also important to understand these warnings are not exhaustive. Detroit Diesel Allison could not possibly know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way. Consequently, Detroit Diesel Allison has not undertaken any such broad evaluation. Accordingly, anyone who uses a service procedure or tool which is not recommended by Detroit Diesel Allison must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects.

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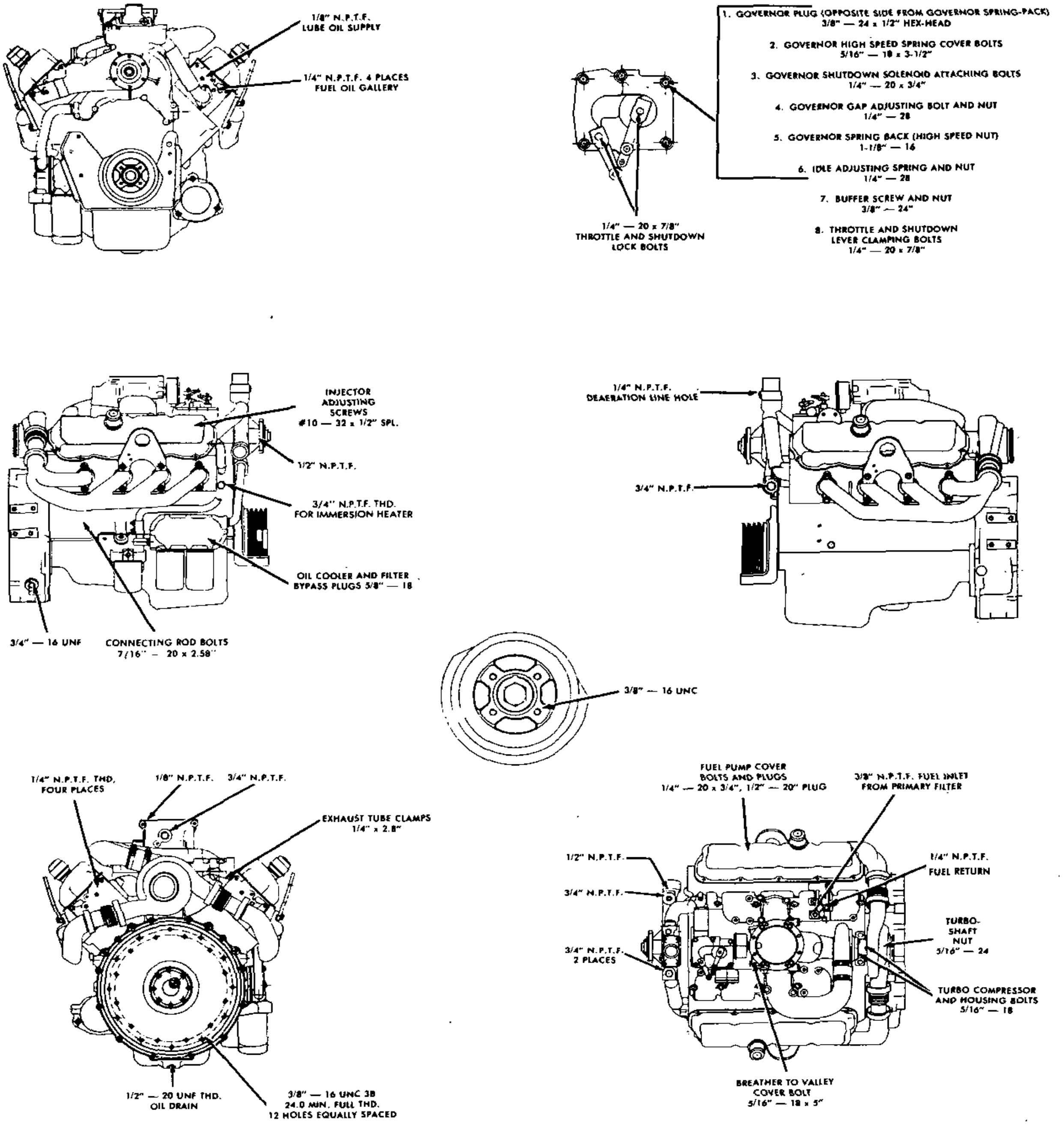


Fig. 1 — Customary Fasteners

GENERAL SPECIFICATIONS

	N.A.	Turbo
Type	4 cycle	4 cycle
Number of Cylinders	8	8
Bore (inches)	4.25	4.25
Bore (mm)	108	108
Stroke (inches)	4.41	4.41
Stroke (mm)	112	112
Compression Ratio	18.3:1	17:1
Total Displacement (cubic inches)	500	500
Total Displacement (liters)	8.2	8.2
Number of Main Bearings	5	5

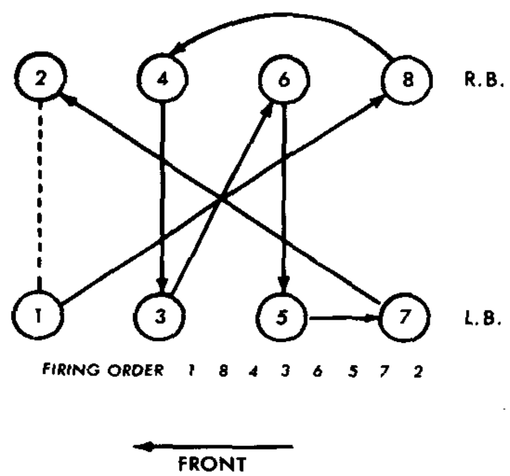


Fig. 2 — Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL

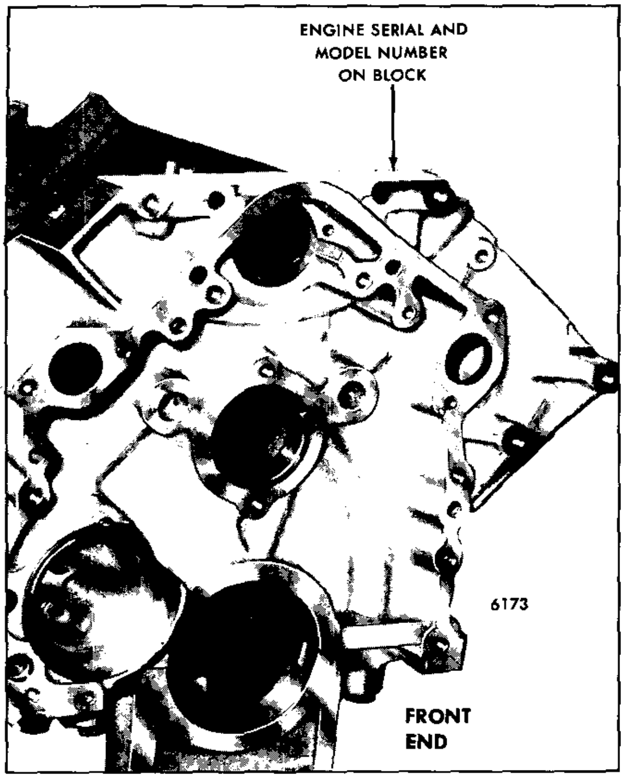


Fig. 3 - Location of Engine Serial and Model Number on Block

The engine serial and model numbers are stamped on a metal plate which is attached to the horizontal machined surface on the front upper part of the block (Fig. 3).

An option label attached to the right valve rocker cover lists the engine serial number and lists any optional equipment used on the engine (Fig. 4).

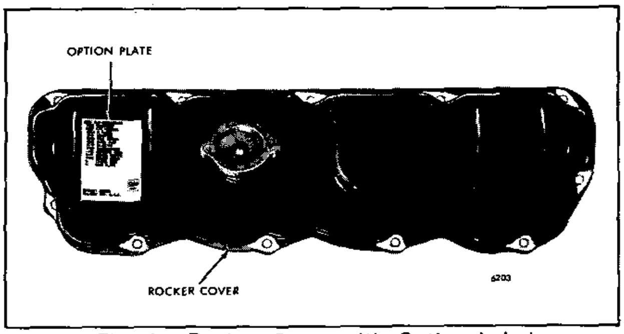


Fig. 4 - Rocker Cover with Option Label

On-highway vehicle engines also carry an exhaust emission control information label on the left rocker cover. Due to Federal regulations, the exhaust emission label should not be removed from the rocker cover. The left rocker cover also has a label which lists injector timing heights for specific cylinder locations.

With any order for parts, the engine model number and serial number should be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups or parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

Power take-off assemblies, torque converters, marine gear, etc. may also carry name plates. The information on these name plates is also useful when ordering replacement parts for these assemblies.

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of burning fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder, then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Four Cycle Principle

The four piston strokes of the cycle occur in the following order: Intake, Compression, Power and Exhaust (Fig. 5).

INTAKE STROKE:

During the intake stroke, the piston travels downward, the intake valve is open, and the exhaust valve is closed.

The downstroke of the piston permits air from outside

to enter the cylinder through the open intake valve port. The turbocharger (when fitted) increases air pressure in the engine intake manifold and forces it into the cylinder, The intake of air is never restricted by carburetion or mixing valves such as those used on spark-ignited, automotive-type gasoline engines.

The intake charge consists of air only with no fuel *mixture.*

COMPRESSION STROKE:

At the end of the intake stroke, the intake valve closes and the piston starts upward on the compression stroke. The exhaust valve remains closed.

At the end of the compression stroke, the air in the combustion chamber has been compressed by the piston to occupy a space about one-seventeenth as great in volume as it occupied at the beginning of the stroke. Thus, we say the compression ratio is 17:1.

Compressing the air into a small space causes the temperature of that air to rise. Near the end of the compression stroke, the pressure of the air above the cylinder is approximately 3 445 to 4 134 kPa (500 to 600 psi) and the temperature of that air is approximately 538 °C (1000 °F).

During the last part of the compression stroke and the early part of the power stroke, a small metered charge of fuel is injected into the combustion chamber.

Almost immediately after the fuel charge is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn.

POWER STROKE:

During the power stroke, the piston travels downward and both intake and exhaust valves are closed.

By the time the piston reaches the end of the compression stroke, the burning fuel causes a further increase in the pressure above the piston. As more fuel is added and burns, the gases get hotter, the pressure increases, pushing the piston downward and adds impetus to crankshaft rotation.

EXHAUST STROKE:

During the exhaust stroke, the intake valve is closed,

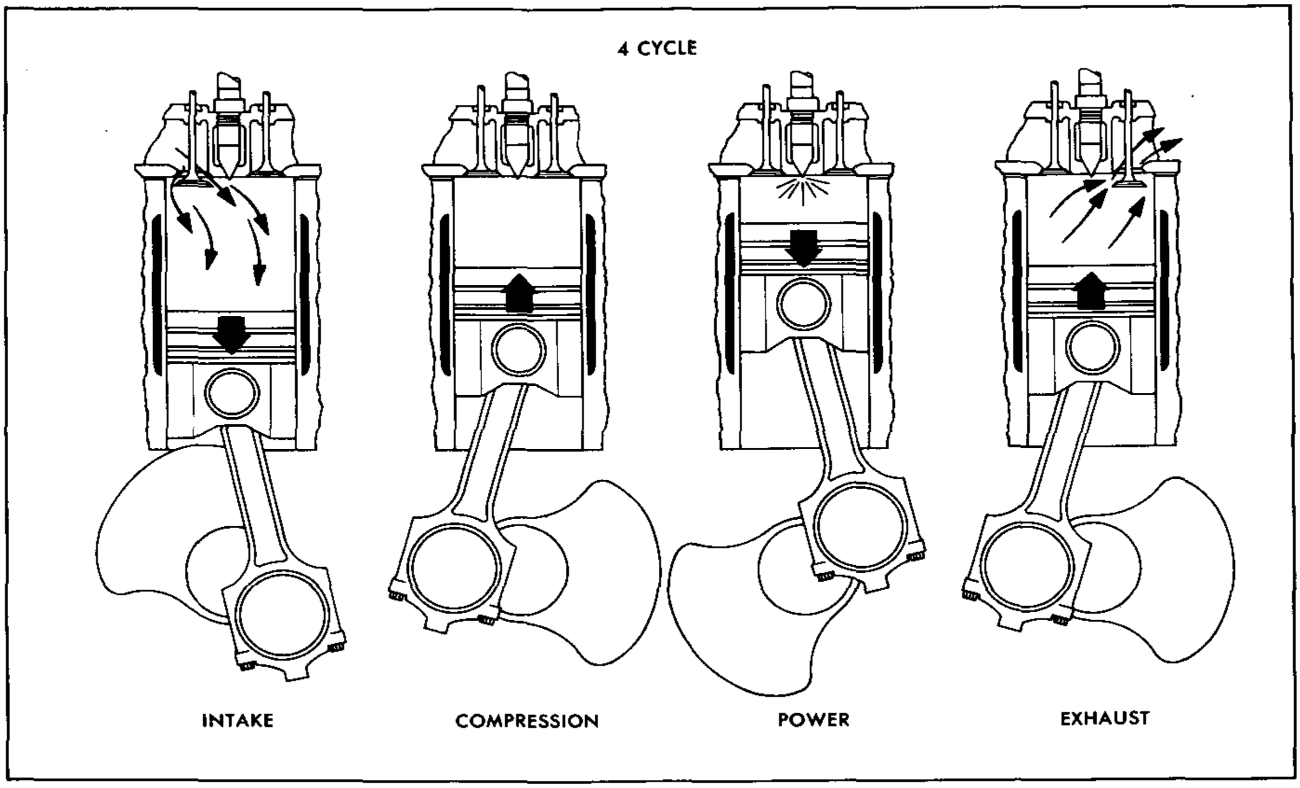


Fig. 5 - The Four Stroke Cycle

the exhaust valve is open, and the piston is on its upstroke.

Burned gases are forced out of the combustion chamber through the open exhaust valve port by the upward travel of the piston.

From the preceding description of the Diesel Cycle, it is apparent that the proper operation of the engine depends upon the two separate functions-first compression for ignition, and, second, that fuel be measured and injected into the compressed air in the cylinder in the proper quantity and at the proper time.

GENERAL DESCRIPTION

The Fuel Pincher Diesel Engine described in this manual is a four-stroke cycle, high speed, full diesel engine.

The 90° "V" cast iron block contains a single camshaft actuating all valves and injectors. The vertically aligned gear train, located at the front end of the engine block contains drive gears for the lubricating oil pump, crankshaft, and camshaft.

Each engine is equipped with a dual full-flow oil filter, fuel oil strainer and fuel oil filter, an air cleaner, governor, fan and a starting motor. The engines are also equipped with an oil cooler.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts. A rotor-type pump draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the radiator. Control of the engine temperature is accomplished by thermostats which regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear-type fuel pump. It is then forced through a filter and into the fuel inlet manifold in the cylinder head and to the injectors. Excess fuel is returned to the supply tank through the outlet connecting line. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air is supplied to the air intake manifolds and into the engine cylinders. All air entering first passes through an air cleaner.

Engine starting is provided by an electric starting motor energized by a storage battery. A battery-charging alternator, with a suitable voltage regualtor, serves to keep the battery charged.

Engine speed is regulated by a mechancial governor.

GENERAL PROCEDURES

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts and other parts are in this category. Exchange assemblies such as injectors, fuel pumps, water pumps and turbos are also desirable service items.

Various factors such as the type of operation of the engine, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation.

For convenience and logical order in disassembly and assembly, the various sub-assemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, coolant and fuel. Lubricating oil should also be drained from any automatic transmission attached to the engine.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various sub-assemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the sub-assemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each sub-assembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block* in Section 1.1; any special cleaning procedures will be mentioned in the text wherever required.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its sub-assemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180-200° F (82-90° C).

Fill the tank with a commercial heavy-duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector.

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools make the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and sub-assemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

WORK SAFELY

A serviceman can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune, take these precautions before starting to work on an engine:

> Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.
>
> Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no-fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc., to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. Always use caution when using power tools.

4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way

damage a component and create a hazardous situation that can lead to personal injury.

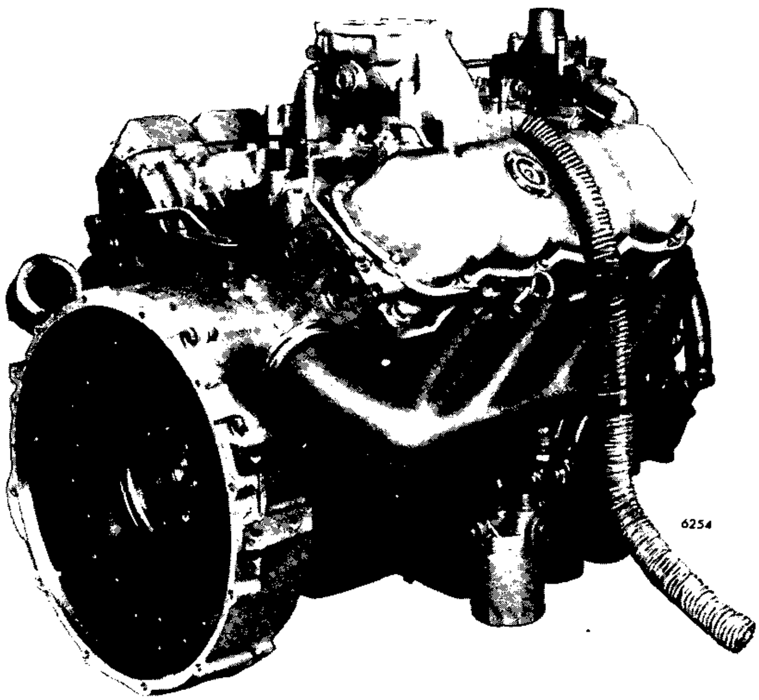
5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

6. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.

7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



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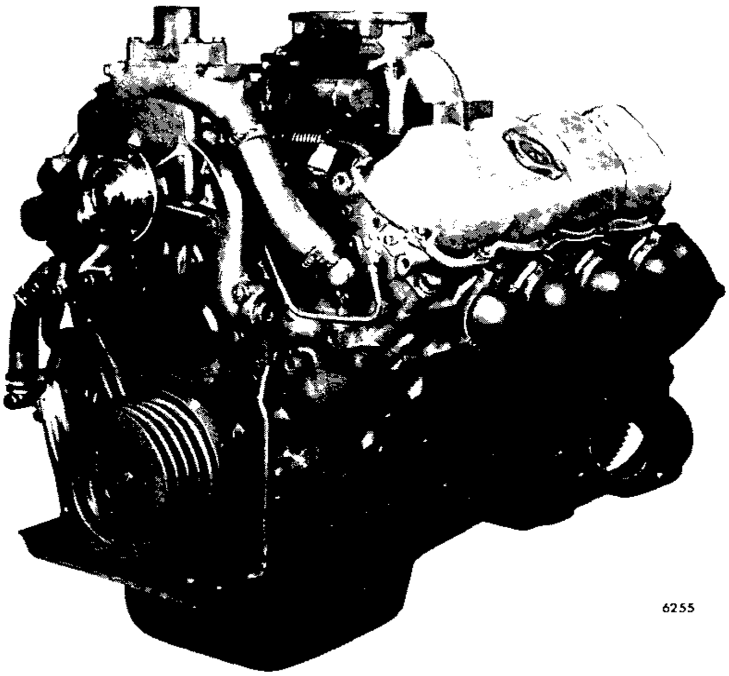

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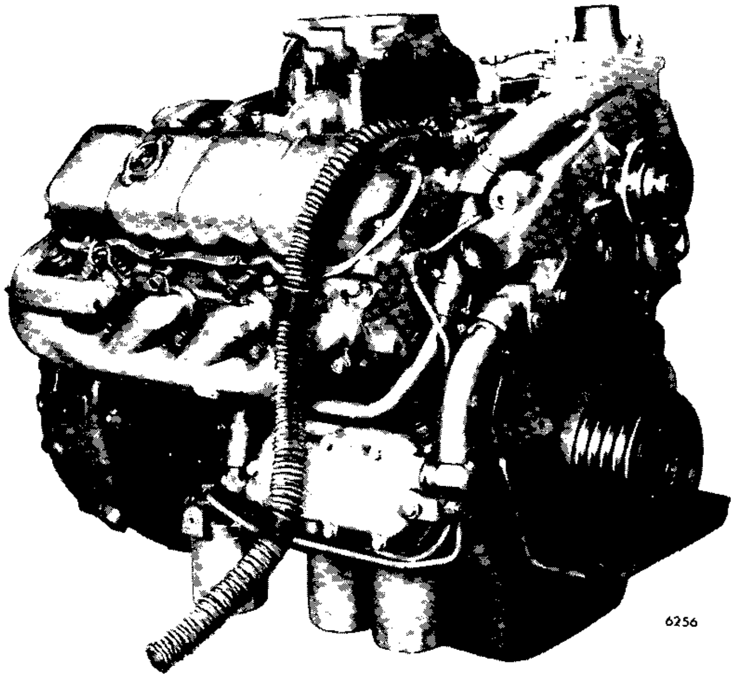
Views of Engine (Naturally Aspirated)



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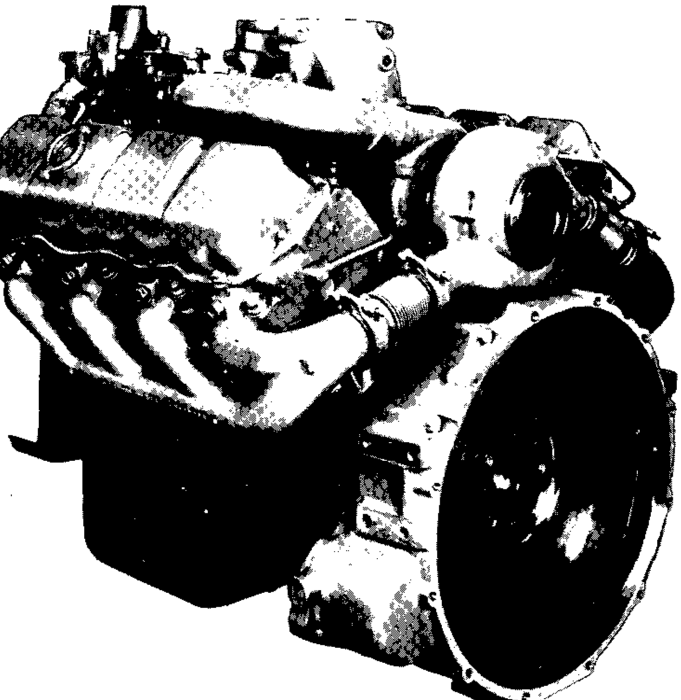

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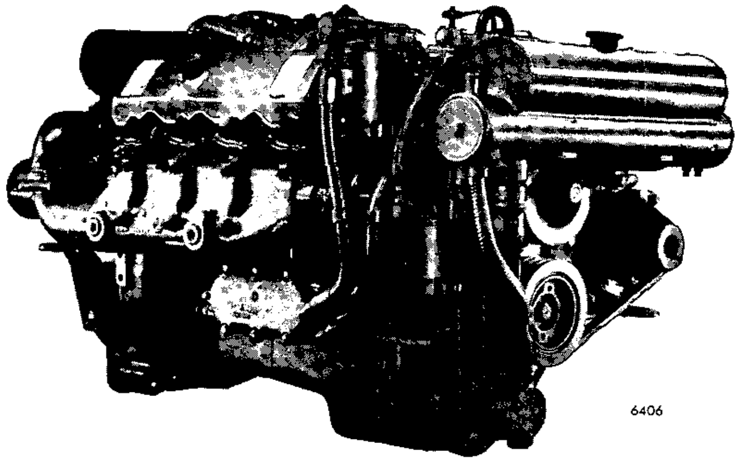
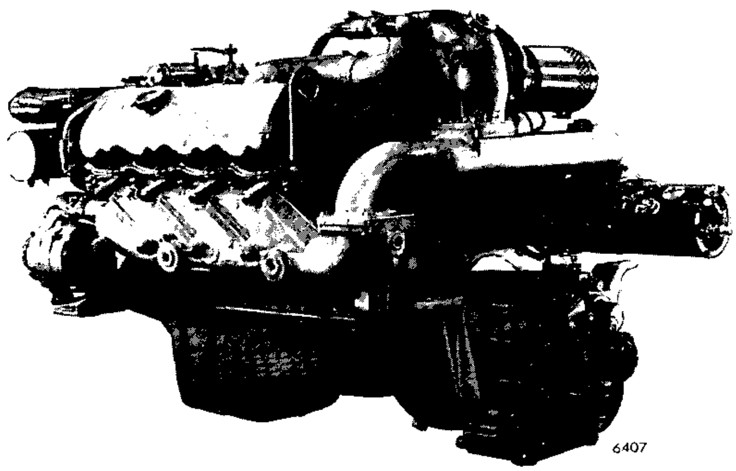
Views of Engine (Turbocharged)





Views of Marine Engine

SECTION 1

ENGINE (*less major assemblies*)

CONTENTS

CYLINDER BLOCK

The cylinder block (Fig. 1) serves as the main structural part of the engine. Webs provide rigidity and strength and ensure alignment of the block bores and bearings under load. A water jacket surrounds all of the cylinders in the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

Since the cylinder block is the main structural part of the engine, the various subassemblies must be removed from the cylinder block when an engine is overhauled.

The overhaul stand J 23935-B and adaptor J *29013*-A (Fig. 2) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90° or 180° where it is locked in place.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be disconnected from the transmission. Details of this procedure will vary from one vehicle to another. However, the following steps will be necessary.

1. Disconnect the battery.

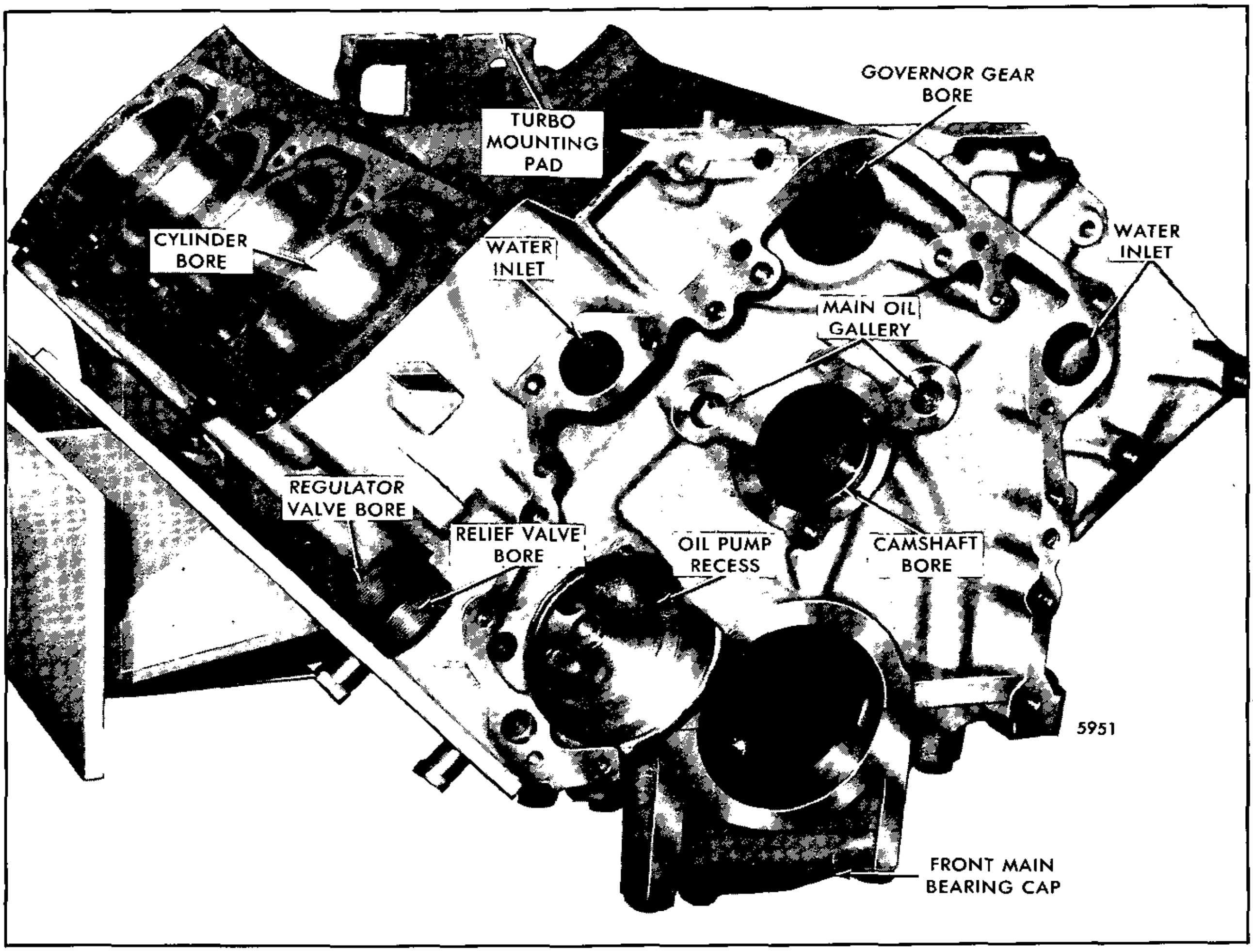


Fig. 1 - Cylinder Block-Front View

2. Remove the starter motor.

3. Drain the cooling system completely by removing the drain plug in the oil cooler, and remove the drain plugs on both sides of the block.

4. Drain the lubricating oil.

5. Disconnect the fuel lines.

6. Remove the air cleaner.

7. Disconnect the exhaust piping.

8. Disconnect the throttle controls.

9. Remove the alternator and the air compressor, if used.

10. Remove the radiator and fan guard and other related cooling system parts.

11. Disconnect any other lubricating oil lines, fuel lines or electrical connections.

12. Separate the engine from the transmission.

13. Remove the engine mounting bolts.

CAUTION: Use a suitable lifting device such as shown in Fig. 3 to lift the engine. A spreader bar should be used with a sling and adequate chain hoist when lifting any engine. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending of the engine lifter brackets. To ensure proper weight distribution, all engine lifter brackets provided should be used in lifting the engine.

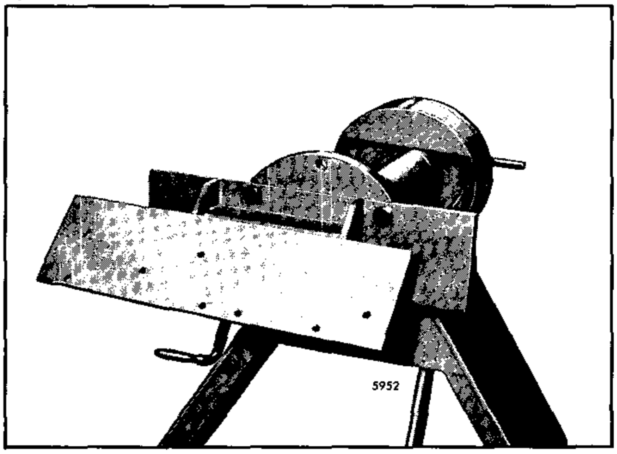


Fig. 2 - Engine Overhaul Stand

14. Lift the engine from its base.

15. Remove the oil filters and oil cooler.

CAUTION: Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

16. With the engine mounted on the overhaul stand, disassemble the engine to a bare block. (Refer to the end of this Section for the removal of the valley cover).

Clean Cylinder Block

Remove all plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning.

Clean the cylinder block as follows:

1. Remove the grease by agitating the cylinder block in a hot bath of commercial heavy-duty alkaline solution.

2. Wash the block in hot water or steam clean it to remove the alkaline solution.

3. If the water jackets are heavily scaled, proceed as follows:

   a. Agitate the block in a bath of inhibited phosphoric acid.

   b. Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).

   c. Lift the block, drain it and reimmerse it in the same acid solution for 10 minutes.

   d. Repeat Step "C" until all scale is removed.

   e. Rinse the block in clear hot water to remove the acid solution.

   f. Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.

   g. Wash the block in clean water or steam clean it.

4. Dry the cylinder block with compressed air. Blow out all of the bolt holes with an air hose and nozzle.

5. Make certain that all water passages and oil galleries have been thoroughly cleaned. After the cylinder block has been thoroughly cleaned and dried, install new

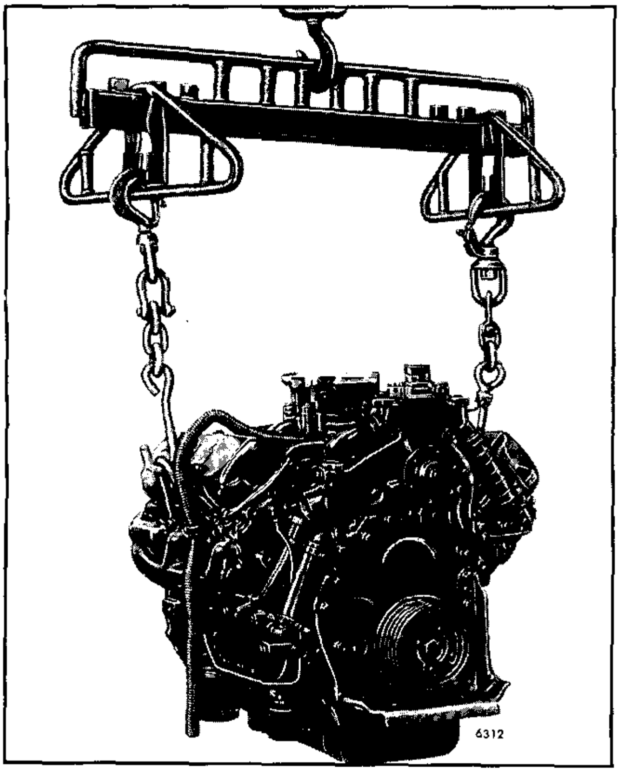


Fig. 3 - Lifting Engine

precoated pipe plugs. See *Block Plugging Charts* in Section 1.0.

Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods.

METHOD "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

1. Install pressure test tool J 29671 on the cylinder block.

2. Attach an air line to the water hole cover plate and apply 276 kPa (40 psi) air pressure to the water jackets.

3. Observe the water in the tank for bubbles which will indicate cracks or leaks. A cracked block must be replaced.

4. Remove the block from the water tank. Then, remove tool J 29671 and blow out all of the passages in the block with compressed air.

METHOD "B"

This method may be used when a large water tank is not available, or when it is desired to check the block for cracks without removing the engine from the vehicle. However, it is necessary to remove the cylinder heads, oil cooler and oil pan.

1. Prepare the block as outlined in Method "A". However, before installing tool J 29671, fill the water jacket with a mixture of water and 3.8 Liter (one gallon) of permanent type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

2. Install tool J 29671.

3. Apply 276 kPa (40 psi) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of this test period, examine the cylinder bores, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced.

5. After the pressure test is completed, remove tool J 29671 and drain the water jacket. Then blow out all of the passages in the block with compressed air.

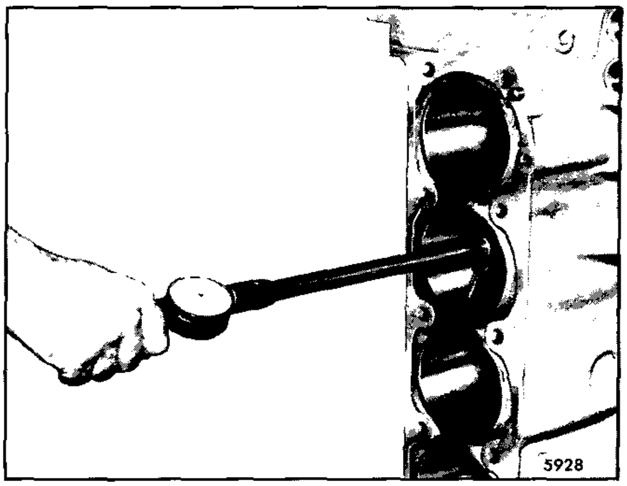


Fig. 4 - Checking Cylinder Bore with Tool J 5347-B

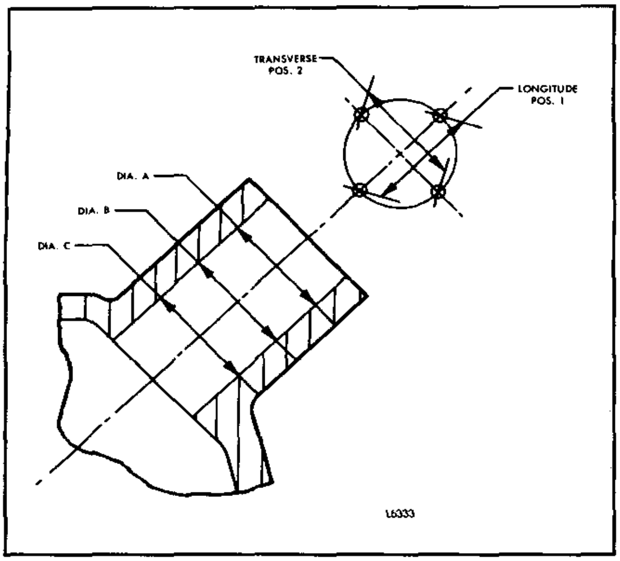


Fig. 5 - Cylinder Block Bore Measurement Diagram

Inspect Cylinder Block

1. Cylinder Bore Measuring

With the main bearing caps torqued to specification and the cylinder block NOT supported by lifting device or mounting stand, proceed as follows:

CYLINDER BORE MEASUREMENT CHART					
CYLINDER	POS.	DIA. A	DIA. B	DIA. C	PISTON SELECTION
NO. 1	1				
	2				
NO. 2	1				
	2				
NO. 3	1				
	2				
NO. 4	1				
	2				
NO. 5	1				
	2				
NO. 6	1				
	2				
NO. 7	1				
	2				
NO. 8	1				
	2				

CHART 1

Measure the cylinder bores with bore gage J 5347-B (see Figs. 4 and 5). Record the measurements in Chart 1. The cylinder bore gage should be calibrated using master setting tool J 23059-01. A hand held micrometer is not recommended for calibration of the bore gage.

Most of the wear will occur at the top of the bore (piston ring travel area).

Cylinder bore tolerances are:

Maximum out of round (compare positions 1 and 2, Fig. 5) 0.025 mm (0.001"). Maximum taper (compare transverse and logitude positions at diameters A, B and C, Fig. 5) 0.025 mm (0.001").

2. Grading the Cylinder Bores

To determine the bore grade refer to measurements recorded in Chart 1. For each cylinder compare the position 2 measurements for diameters B and C. Select the smallest of these two diameters (B/C) and refer to the bore grade (Chart 2).

If the No. 1 cylinder diameter B, position 2 is 108.146 mm (4.2577") and diameter C, position 2 is 108.148 mm (4.2578"); the 108.146 mm (4.2577") is the smallest of diameters B and C. The bore grade Chart (Chart 2) shows this diameter is within a grade "B" 0.127 mm (0.005") oversize. Therefore, No. 1 cylinder would be grade "B" 0.127 mm (0.005") O/S.

Standard size pistons are available in (3) different grades (A, B and C) each identified by a separate part number. This is to facilitate piston installation in a factory machined block since cylinder bore sizes may vary slightly.

Oversize pistons 0.127 mm (0.005"), 0.254 mm (0.010") and 0.508 mm (0.020") for naturally aspirated or turbocharged engines are available.

Only one part number has been released for each oversize piston. The O/S piston will have the grade identification stamped on the dome next to the part number.

The design of the piston is such that the diameter cannot be accurately measured in the field without sophisticated gaging and temperature controlled environment. An ordinary micrometer will not provide accurate piston diameter dimensions.

After determining the size of the worn cylinder bore, check parts stock to ensure that the required piston size is in stock. If the piston is not in stock, it is acceptable to go to the next grade larger piston.

CYLINDER BORE DIAMETERS			
PISTONS	**A**	**B**	**C**
Standard	108.00 - 108.016 mm (4.2520 - 4.2525″)	108.017 - 108.033 mm (4.2526 - 4.2532″)	108.034 - 108.050 mm (4.2533 - 4.2539″)
0.127 mm (.005″) O/S	NOT AVAILABLE	108.144 - 108.160 mm (4.2576 - 4.2582″)	NOT AVAILABLE
0.254 mm (.010″) O/S	NOT AVAILABLE	108.271 - 108.287 mm (4.2626 - 4.2632″)	NOT AVAILABLE
0.508 mm (.020″) O/S	NOT AVAILABLE	108.525 - 108.541 mm 4.2726 - 4.2732″)	NOT AVAILABLE

CHART 2

Inspection and measuring procedures for the cam bushing bores and the oil pump bore can be found in Sections 1.7.2 and 4.0 respectively. Honing, boring and sleeving procedures can be found in Section 1.0.

3. Cylinder Block Firedeck Flatness

Check the top of the block for flatness through the center of the bores only with an accurate straight edge and a feeler gage (Fig. 6). The top surface must not vary more than .07 mm (.003″) transversely and not over .17 mm (.007″) longitudinally.

The bolt hole bosses (Fig. 7) occasionally will protrude above the fire deck of the cylinder block on one or both banks after the engine has been operated for some period of time. When checking the fire deck for flatness, a raised bolt hole boss area can cause a reading indicating that the fire deck is warped, when in fact it is not.

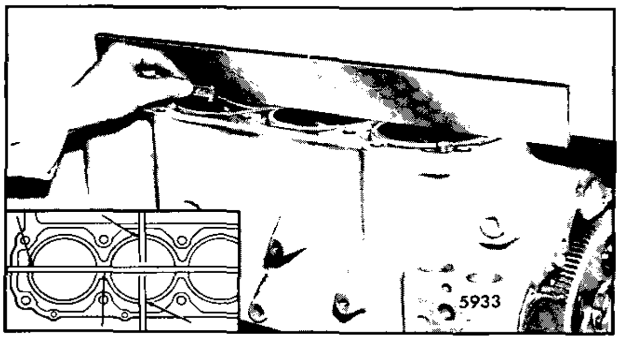


Fig. 6 - Checking Top of Block for Flatness

In order to correct this condition, the following procedure should be followed:

a. Perform a flatness check in the locations indicated in Fig. 8.

b. Should the bolt hole bosses be found to protrude above the fire deck in excess of 0.09 mm (0.0035″), they should be draw filed and stoned down to 0.09 mm (0.0035″). It is not necessary to return the bolt boss to 0.00 mm (0.00″).

4. Main Bearing Bores

Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions (Fig. 9). Lubricate the bolt threads and bolt head contact area with a small quantity of International Compound No. 2, or equivalent. Then, install and tighten the outer

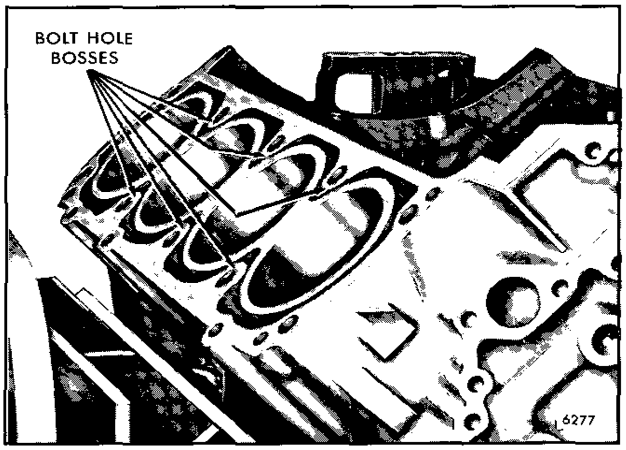


Fig. 7 - Bolt Hole Boss Locations

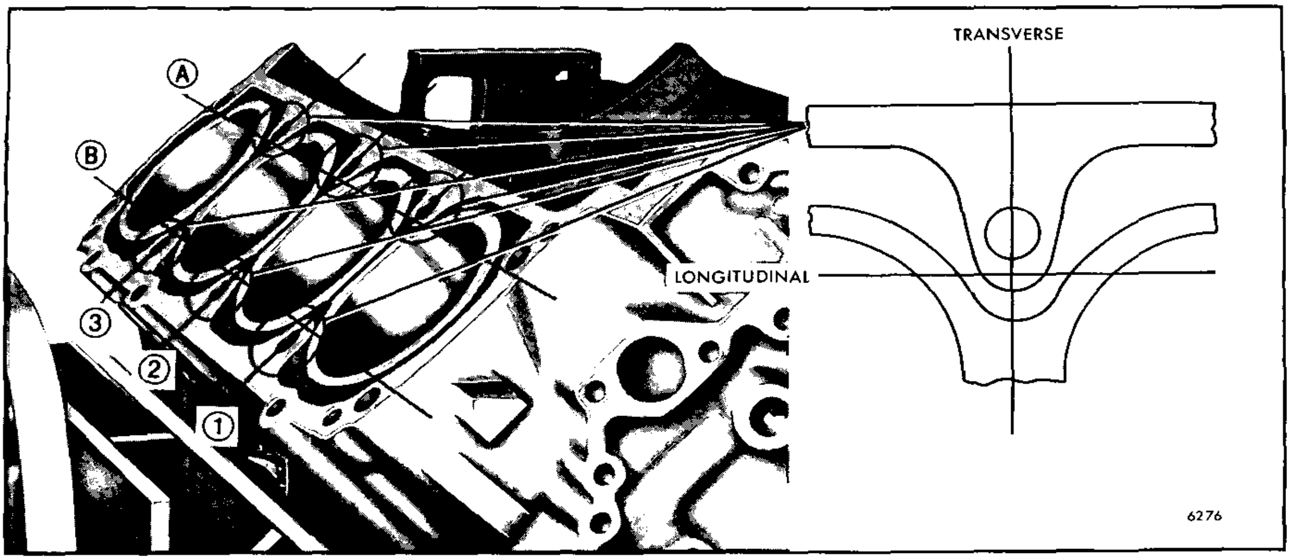


Fig. 8 - Flatness Check Locations

bolts to 90-103 Nm (66-76 lb-ft), and the inner bolts to 140-160 Nm (103-118 lb-ft). Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. The specified bore diameter is 106.430 mm (4.190") to 106.455 mm (4.191"). If the bores do not fall within these limits, the cylinder block must be rejected or reworked. See Section 1.0 for rework procedures.

Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block.

b. Finished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

c. Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. If a main bearing bore is more than .025" mm (.001") out of alignment, the block must be line bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment or a replacement bearing cap is used, the block must be line bored. Install the bearing caps in their original positions and tighten the bolts to the specified torque. Line bore the block, but do not remove more than .025 mm (.001") stock. After boring, all bores must be within the specified limits.

5. Install all of the necessary plugs in the block. Replace loose or damaged dowel pins. See Block Plugging Charts in Section 1.0.

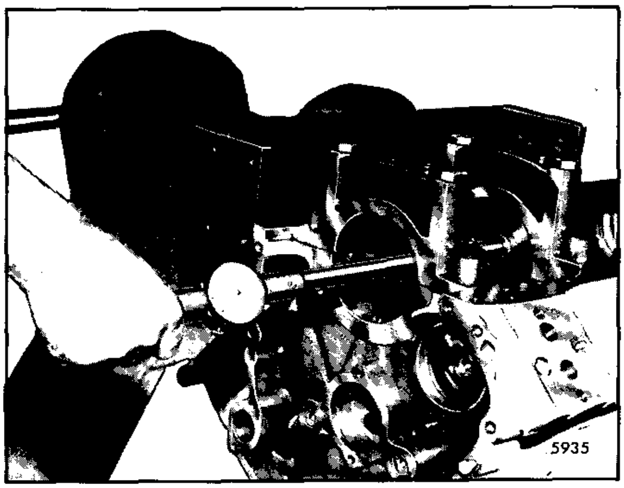


Fig. 9 - Measuring Main Bearing Bores

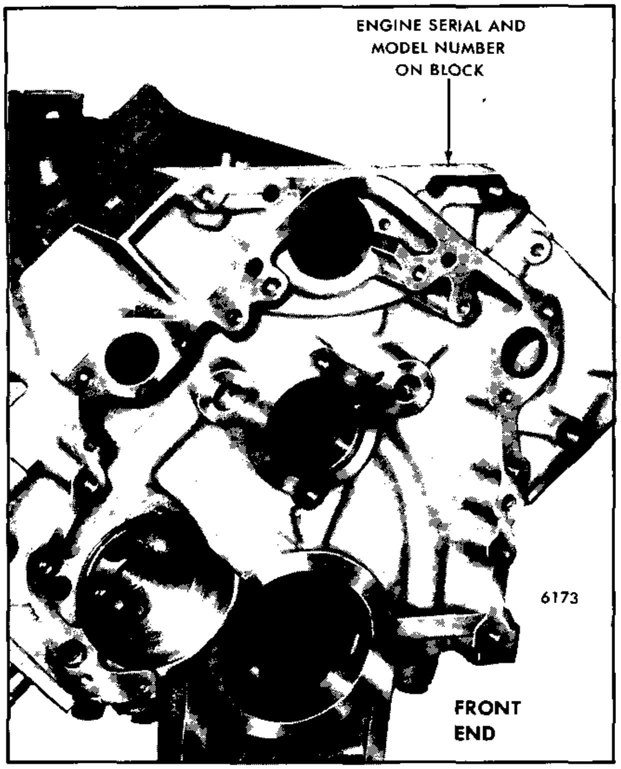


Fig. 10 - Location of Engine Serial and Model Number on Block

6. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean up damaged threads in tapped holes with a tap or install helical thread inserts except outer main bearing and head bolt holes.

7. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

Assemble and Install Engine

Whenever a new cylinder block, crankshaft, camshaft or timing gear is installed, any previously determined injector timing heights are no longer valid. New base circle timing heights must be established by precision timing the engine (refer to Section 14.2.1). Before a reconditioned or new service replacement cylinder block is used, thoroughly clean it to remove the rust preventive and blow out the oil galleries with compressed air.

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

1. Mount the block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number on the block in the same place as the identification label is now located (Fig. 10). Also, stamp the position numbers on the main bearing caps and the position of the No. 1 bearing on the oil pan mounting flange of the block.

3. Install all of the required plugs. Cup plugs should be cleaned prior to the application of a sealant. See Block Charts in Section 1.0. Whenever a pipe plug is removed from the cylinder block, do not reinstall the same plug. Install a new precoated pipe plug.

4. Clean and inspect all of the engine parts subassemblies and using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. Refer to the end of this section for the installation of the valley cover). The procedures for inspecting and installing the various parts and subassemblies are outlined in the following sections of this manual.

5. Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls, etc. and reinstall the engine in the vehicle.

Remove Valley Cover
(Cylinder Heads Installed)

1. Remove air inlet ducting and turbocharger, if used.

2. Disconnect fuel lines from fuel pump.

3. Remove fuel junction block.

4. Remove both air intake manifolds. Cover air intake ports of cylinder heads with shop towels to prevent dirt or other objects from entering the engine.

5. Remove water outlet cover L/B rear and water outlet elbow R/B front.

6. Remove valve rocker covers. Discard the gaskets.

7. Remove Nos. 1 and 2 cylinder rocker arm assemblies.

8. Remove governor control link tube bolts and boot clamps.

9. Disconnect and remove governor control linkage (governor to injector rack control tube). Then, remove the governor control link tube, boot and clamps.

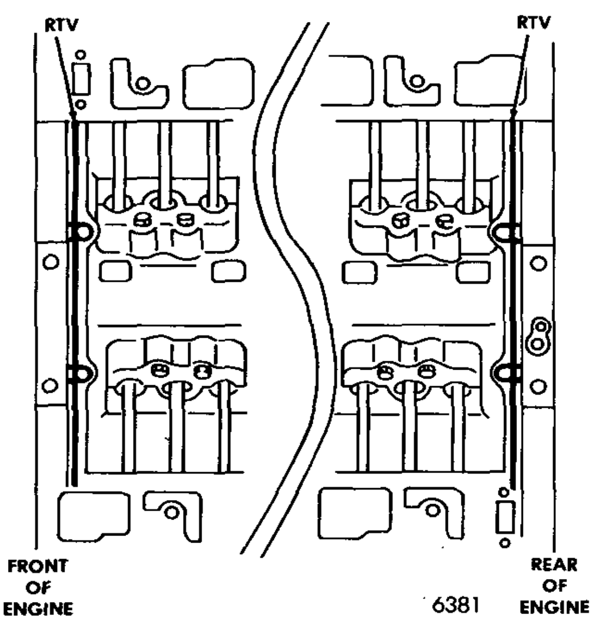
10. Remove the governor and fuel pump as an assembly.

11. Remove the two valley cover stiffener brackets, bolts and beveled washers.

12. Remove valley cover and valley cover to head side seals. Cover valley section of block with shop towels to prevent dirt or other objects from entering the engine. Remove all gasket material from the block, the heads and the intake manifolds. Clean valley cover.

Install Valley Cover (Cylinder Heads Installed)

1. Remove the shop towels.



Apply a 6mm (¼") Dia. bead of RTV as shown prior to valley cover ass'y. Do not allow RTV to stand for more than 10 minutes before installing cover.

Fig. 11 - RTV Locations

2. Apply Room Temperature Vulcanizer (RTV) sealer or equivalent (Fig. 11).

3. Install the cover to head side seals on the valley cover.

4. Place the valley cover assembly on the block over the front and rear gaskets.

5. Place a valley cover stiffener bracket at each end with the bolt holes in alignment.

6. Install two bolts and two beveled washers in each bracket. Tighten the bolts to 23-27 Nm (17-20 lb-ft) torque.

7. Install water outlet cover L/B rear and water outlet elbow R/B front.

8. Install governor/fuel pump assembly.

9. Install intake manifolds. Tighten the bolts to 46-53 Nm (34-39 lb-ft) torque.

10. Install governor control linkage, governor control link tube, boots and boot clamps.

11. Adjust the governor control linkage to injector rack control tube as outlined in Section 14.3 under "Governor Control to Injector Rack Connection".

12. Install Nos. 1 and 2 cylinder rocker arm assemblies. Tighten bolts to 46-53 Nm (34-39 lb-ft) torque.

13. Confirm injector timing and valve lash of cylinders Nos. 1 and 2 (where rocker arm assemblies were removed). If found to be out of specifications, adjust as outlined in Section 14.2 (Nos. 1 and 2 only).

14. Install fuel junction block.

15. Install fuel lines.

16. Install the turbocharger, if used.

17. Install valve rocker covers with new gaskets. Tighten bolts to 23-27 Nm (17-20 lb-ft) torque.

CYLINDER HEAD

The cylinder head (Fig. 1) is a one-piece casting securely held to the top of the cylinder block bank with ten bolts.

The valves, fuel injectors and some of the valve and injector operating mechanisms are located in the cylinder head.

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube which passes through the water space in the cylinder head. The injector tube is sealed with an "O" ring seal. The sealed end of the injector tube prevents water and compression leaks.

A tube type heat shield is used in each cylinder head exhaust port. The tube creates dead air space to minimize heat transfer to the water jacket.

The fuel gallery is an integral part of the cylinder head. Tapped holes are provided for connection of the fuel lines at each end of the cylinder head.

To seal compression between the cylinder head and the cylinder block a laminated metal gasket is provided at each cylinder head. When the cylinder head is drawn down, a positive leakproof seal is assured between the head and the block.

Cylinder Head Maintenance

The cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. An overheated engine should be allowed to cool before any water is added. Then, add water slowly to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to find the cause and avoid a recurrence of the failure. Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. The cylinder head should be inspected around the valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, use a reliable noncorrosive scale remover to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to 10-12 Nm (7-9 lb-ft) torque.

Other conditions which may eventually result in cylinder head cracks are:

1. Excess fuel in the cylinder caused by leaking injectors.

2. Slipping fan belts can cause overheating by reducing air flow through the radiator.

3. Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.

4. Inoperative radiator cap which will result in loss of coolant.

Remove Cylinder Head

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then, remove the cylinder head as follows:

1. Drain the cooling system.

2. Disconnect the exhaust piping at the exhaust manifold.

3. Remove the air cleaner.

4. Remove the air intake manifold.

5. Disconnect the fuel lines.

6. Remove the water connection at the front of the head.

7. Clean and remove the valve rocker cover.

8. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover.

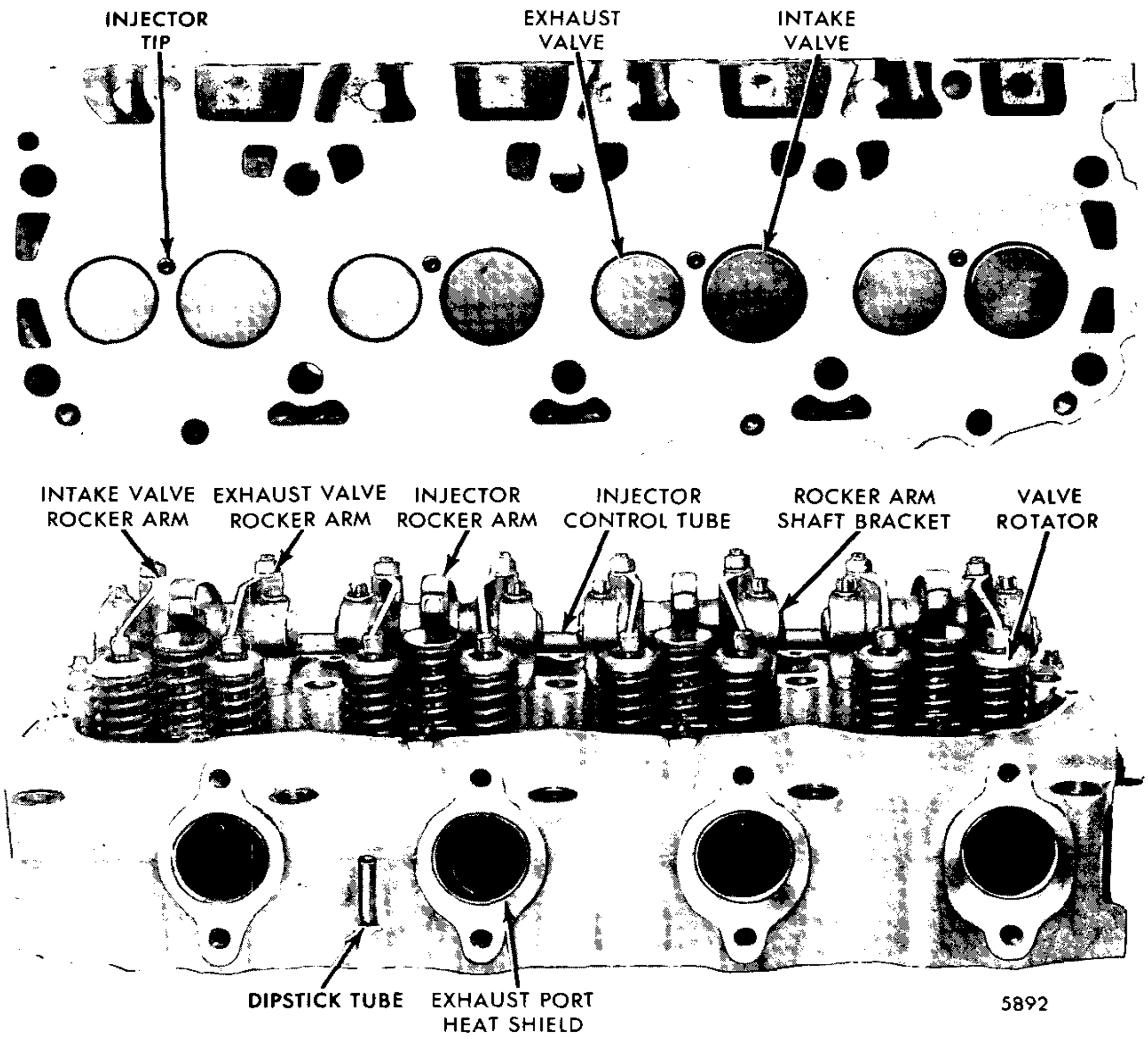


Fig. 1 - Cylinder Head Assembly

9. Disconnect the clamp at the turbocharger tube and remove the exhaust manifold.

10. Remove the valve and injector rocker arms, shafts and brackets.

11. Remove the injector control tube and brackets as an assembly. Remove the push rods.

12. If the cylinder head is to be disassembled for reconditioning of the valves or for a complete overhaul, remove the fuel injectors at this time.

13. Check the torque on the cylinder head bolts before removing the head. Then, remove the bolts and lift the cylinder head from the cylinder block using a suitable lifting tool. Checking the torque before removing the head bolts and examining the condition of the head gaskets after the head is removed may reveal the causes of any cylinder head problems.

> **NOTE:** When placing the cylinder head assembly on a bench, protect the injector spray tips, if the injectors were not removed, by resting the valve side of the head on wood blocks.

14. Remove and discard the cylinder head gasket.

15. After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes. Then clean the cylinder head in the same manner as outlined by cleaning the cylinder block (Section 1.1).

Clean all of cylinder components with fuel oil and dry them with compressed air.

Inspect Cylinder Head

1. Pressure check the cylinder head as follows:

a. Install tool J 29670-A on cylinder head.

b. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Tighten the injector clamp bolts to 10-12 Nm (7-9 lb-ft) torque.

c. Apply 138 kPa (20 psi) air pressure to the water jacket. Then, immerse the cylinder head in a tank of water, previously heated to 82-93° C (180-200° F), for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicates a leak or crack. Check for leaks at the top and bottom of the cylinder head.

d. Relieve the air pressure and remove the cylinder head from the water tank. Then, remove tool J 29670-A and the injectors and dry the head with compressed air.

e. If the pressure check revealed any cracks, install a new cylinder head.

2. All cylinder head exhaust port heat shields do not have to be replaced at the same time. Inspect each heat shield at the time of major overhaul or during cylinder head rework as follows:

a. Remove the heat shield from the cylinder head and inspect the outside diameter for carbon deposits. If carbon is visible replace the heat shield.

b. If carbon is not visible, the shield should be further inspected inside and out for cracks, dents, tears, or any other damage.

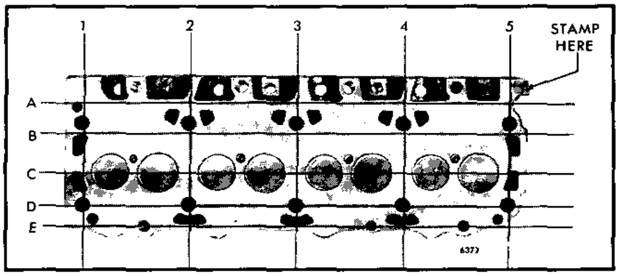


Fig. 2 - Checking Fire Deck Flatness

If no damage is evident reinsert the heat shield in its original location.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the fuel gallery before installing. A simple method of removing the rust preventive compound is to immerse the head in a mineral spirits based solvent or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. After cleaning, dry the cylinder head with compressed air.

Fire Deck Flatness

Check the cylinder head fire deck flatness with an accurate straight edge and a feeler gage as indicated in Fig. 2. The maximum allowable variance of the head surface is: .15mm (.006") longitudinal (positions A, B, C, D & E) and .10mm (.004") transverse (positions 1, 2, 3, 4 & 5). If the head is out of specifications it must be replaced or resurfaced. The fire deck can be resurfaced to a maximum of .38mm (.015") or a minimum fire deck to rocker cover gasket area dimension of 114.3mm (4.5") whichever occurs first (see Fig. 3).

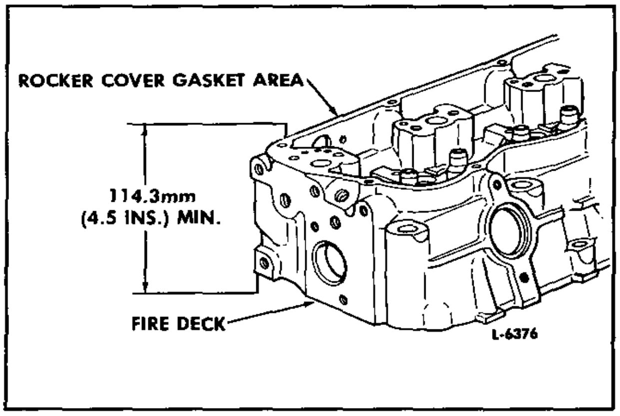


Fig. 3 - Fire Deck Resurfacing Specification

The surface finish required is 2.8 micrometers (110 microinches) maximum. Surface waviness must not exceed .008mm (.0003") in 2.5mm (.098") minimum.

NOTE: The surface finish and waviness are critical for cylinder head gasket sealing.

When the fire deck is resurfaced, it will be becessary to:

1. Stamp the amount of stock removed on the face of the fire deck, away from the combustion or sealing areas in the location shown on Fig. 2.

2. Install new injector tubes and seals (reference Section 2.1.4) and pressure test the cylinder head.

3. Check to ensure intake and exhaust valves are .00-.9mm (.00-.035") below the fire deck of the cylinder head. Grind the valve seats, if necessary to obtain this specification.

Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

1. Install new precoated pipe plugs and tighten them to the specified torque (see cylinder head plugging chart in Section 1.0).

2. After the following parts are cleaned and inspected, and replaced if necessary, reinstall them in the old cylinder head or transfer them to the new head.

   a. Install the valves and springs.

   b. Install the control tube assembly on the head.

   c. Install the fuel injector.

Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service only the head or to facilitate other repairs to the engine.

1. Make sure the piston crowns are clean and free of foreign material.

2. Check the cylinder block and cylinder head gasket surfaces, to be sure they are clean and free of foreign material.

3. Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes thoroughly and check for damaged threads.

Install Cylinder Head

1. Attach a suitable lifting sling (Fig. 4) to the cylinder head and lift the head into position above the cylinder block.

2. Make a final visual check of the new gasket to ensure it is in place before the cylinder head is lowered.

3. Wipe the bottom of the cylinder head clean. Then, lower the head over the dowel pins in the cylinder block.

4. Place a special flat washer on each cylinder head bolt. Apply a small quanity of International Compound No. 2 or equivalent, to the threads of each cylinder head attaching bolt and the underside of the bolt head. Then, install the bolts finger tight.

NOTE: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

5. Tighten the bolts to 196 Nm (145 lb-ft) torque with a torque wrench, about one-half turn at a time. Tighten the bolts in the sequence shown in Fig. 5.

6. Cover the oil drain holes in the cylinder head to prevent foreign objects from falling into the holes.

7. If the fuel injectors were not previously installed, install them at this time.

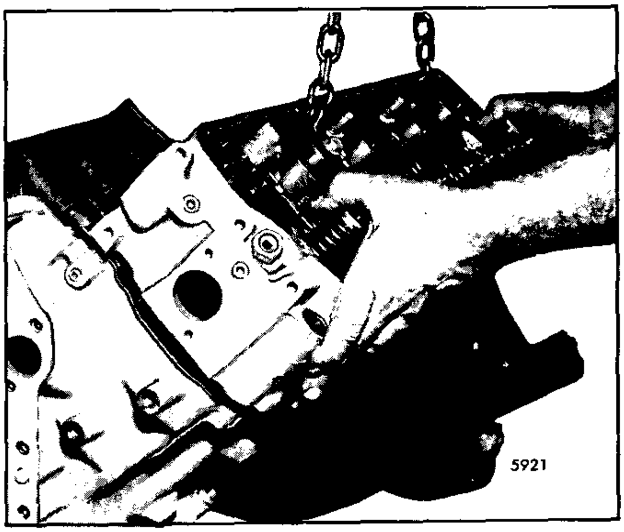


Fig. 4 - Lifting or Installing Cylinder Head

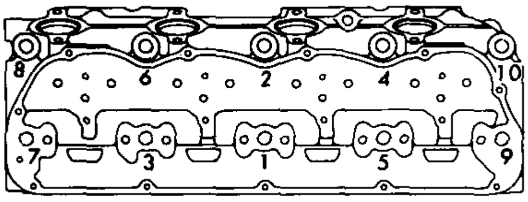


Fig. 5 - Cylinder Head Bolt Tightening Sequence

8. Install the valve and injector push rods through the holes in the head and position the ends in the cam follower in the block.

9. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With the control tube return springs in their proper position, tighten the bracket bolts to 30-34 Nm (22-25 lb-ft) torque.

10. After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector rack out (no-fuel position) after they have been moved all the way in (full-fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks must return to the no-fuel position freely by aid of the return spring only. Do not bend the spring. If necessary, replace the spring.

11. Install the fuel rod and the fuel rod cover boot and clamps. Tighten the clamps.

a. Adjust the governor to injector control rack links (Section 14.3).

b. Install the rocker arms, shafts and brackets (Section 1.2.1).

12. Remove the covers from the drain holes in the cylinder head, previously installed in Step (6) six.

13. Use new gaskets and install the rocker cover.

14. Install the air intake manifold(s) using new gaskets.

15. Install the air inlet housing and air cleaner.

16. Install the exhaust manifold(s) and connect the exhaust piping using new gaskets.

17. Install the water outlet elbow to the front of the cylinder head. Connect the water hoses and tighten the water hose clamps.

18. Connect the fuel lines.

19. Install any other equipment that was previously removed.

20. Fill the cooling system and lubrication system.

21. Before starting the engine perform an engine tune-up as outlined in Section 14.

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust and intake valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the valve springs.

The rocker arms are operated by a camshaft through cam followers and long push rods extending through the cylinder head.

Each cam follower operates in a bore located in the cylinder block valley (Fig. 1). A guide for each set of three cam followers is attached to the cylinder block to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes. A coil spring, inside of the injector cam follower, maintains a predetermined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

Lubrication

The valve and injector operating mechanism is lubricated by oil from the longitudinal oil passage in the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through passages in the rocker shaft bracket to the passages in the rocker arm shaft to lubricate the rocker arms.

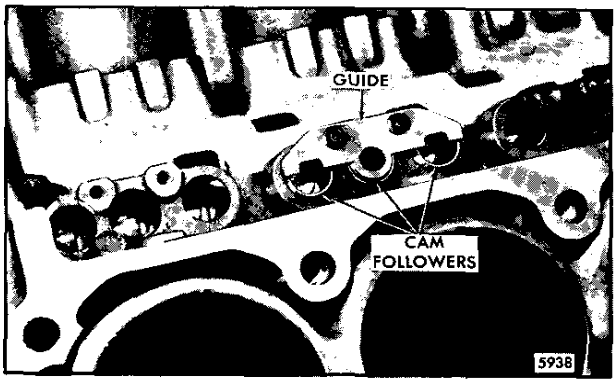


Fig. 1 - Location of Cam Followers and Guide in Block

The cam follower rollers are lubricated by oil draining from the cylinder head through the push rod holes and crankshaft oil throw off.

Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head.

1. Adjust valve clearance.
2. Replace a valve spring.
3. Replace a rocker arm.
4. Replace a rocker arm shaft or bracket.
5. Replace valve and injector push rods.
6. Replace a fuel injector.

To replace the intake and exhaust valves the cylinder head must be removed.

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover.
2. Loosen the locknut and back out the adjusting screw to relieve the tension on the valve and injector spring.
3. Loosen the rocker shaft bolts and remove the rocker arm shafts and supports.

> **NOTE:** If the rocker arms and shafts are to be removed from two or more cylinders, tag them so they may be reinstalled in their original positions.

Inspection

Wash the rocker arms, shaft, brackets, and bolts with clean fuel oil. Clean out any oil passages in the above parts. Dry the parts with compressed air.

Inspect the rocker arm shaft and injector rocker arm bores for wear. Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces). If worn, the surface may be ground up to a maximum of .25 mm (.010"). Use care when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible.

Remove Cam Follower and Push Rod

When removing the cam followers, push rods and associated parts, tag them so they may be reinstalled in their original location.

To remove the cam followers located in the cam bores in the cylinder block valley, the valley cover must first be removed (see Section 1.1).

1. To remove the push rods, remove the two rocker shaft bracket hold down bolts. Lift the brackets, shaft, and rocker arms from the cylinder head.

2. Remove two bolts and lift out the cam follower guide.

3. Remove the spring from the (center) group of three cam followers.

4. Lift the cam followers from the bores in the cylinder block.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed. Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. Do not use fuel oil. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and follower guides may be washed with clean fuel oil and dried with compressed air.

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diameter clearance and side clearance. The total diameter clearance for the injector and cam follower pin to bushing (clearance) is .033 mm-.053 mm (.0013″-.0021″), max. .102 mm (.004″). The injector cam follower side clearance is .27 mm-.58 mm (.011″-.023″) and the valve cam follower side clearance is .4 mm-.6 mm (.016″-.024″).

Examine the camshaft lobe for scoring, pitting or flat spots. Replace the camshaft, if necessary.

Check the cam follower-to-cylinder block clearance. The clearance must not exceed .127 mm (.005″) with used parts.

Examine the cam follower bores in the cylinder block to make sure they are clean, smooth and free of score marks. If necessary, clean up the bores. Examine the injector cam follower spring for wear or damage and check the spring load.

Use valve spring tester J 22738-02 to check the spring load. Replace a spring if a load of less than 511.55 N (115 lbs.) will compress the spring to a length of 31.75 mm (1.25″).

There are two methods that may be used for checking the straightness of the push rods.

The first method requires the use of a confirmed flat surface plate having a width of ten and one-half inches. Use a feeler gauge to check the clearance at the center of the push rod between the flat surface and shaft while rotating or rolling the push rod.

The second method requires the use of "Vee" blocks and a dial indicator. Vee blocks must be set to a maximum outside dimension of ten and one-half inches and dial indicator readings are to be taken at the center of the push rod. Rotate the push rod within the Vee blocks and check the dial indicator readings for a bent shaft.

Replace only those push rods found to exceed .20 mm (.008″) max. runout variation with either the feeler gauge or the dial indicator.

Do not attempt these inspection methods by rolling the push rod on the ball and cup ends, since the ends may be slightly off-center. Such a condition will not affect engine operation, however, an accurate straightness check of the shaft cannot be made.

Install Cam Follower

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. Do not use fuel oil. Before cam followers are installed, immerse them in clean Cindol 1705 heated to 38-52 ° C (100-125° F) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705; the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

> **NOTE:** Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail and avoid the possibility of contamination.

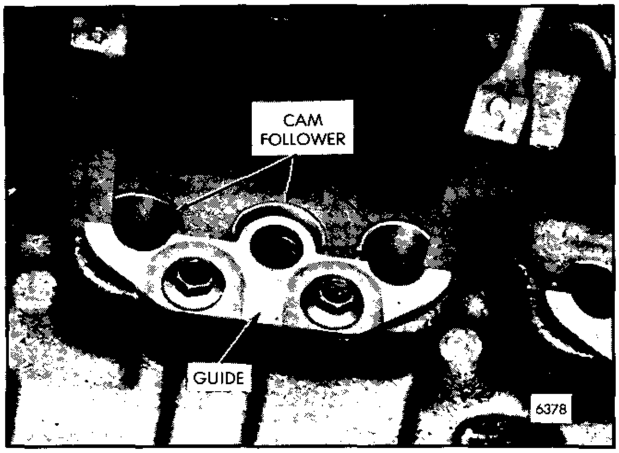


Fig. 2 - Installing Cam Follower Guide

Install used cam followers and push rods in their original locations.

1. Slide the cam followers in position in the cylinder block cam follower bores.

2. Place a spring in the body of the center cam follower (injector) only.

3. Attach the follower guide to the cylinder block to hold the group of three cam followers in place.

4. Guides are to be set with .25 mm (.010") clearance (.127 mm (.005") each leg) between the guide and follower body, as shown in Fig. 2. Tighten the guide bolts to 23-27 Nm (17-20 lb-ft) torque. Make sure the guide is not binding the followers. If it is, loosen the guide bolts slightly and tap each corner of the guide with a brass rod until there is no ginding. Then, retighten the bolts to the specifeid torque.

5. Install the injector and valve push rods through the proper holes in the head and locate them in the cam followers.

Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is different from the valve rocker arms.

NOTE: Install with the exhaust rocker arm to the front of the engine on the right bank and to the rear of the engine on the left bank.

1. Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then, place a bracket over each end of the shaft.

2. Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to 46-53 Nm (34-39 lb-ft) torque. Check to make sure there is some clearance between the rocker arms.

NOTE: During the assembly or replacement of the push rods and the rocker arms caution must be used to insure that the ball end of the rocker arm adjusting screw is seated in the cup of the push rod when the rocker shaft bracket bolts are being tightened down. This will prevent the ball from being pulled down on the top edge of the cup, which could result in bending the push rod and/or damage to the cup.

3. Align the push rods with the rocker arm adjusting screws.

4. Adjust the intake and exhaust valve clearance and time the injectors.

5. Perform an engine tune-up (refer to Section 14).

VALVES

Two valves are provided for each cylinder. One is an exhaust valve and the other is an intake valve. The valve heads are heat treated and ground to the proper seat angle and diameter. The intake valve has a larger O.D. head. The valve stems are ground to size and hardened at the end, which contacts the valve rocker arm.

The valve stems are contained within guides which are machined into the cylinder head casting. Exhaust valve seats are ground into a hardened area in the cylinder head.

A valve guide oil seal is used at both the exhaust and intake valve.

The valve spring assembly is held in place by the valve rotator (Fig. 1) and tapered two-piece valve locks.

Valve Maintenance

Efficient combustion in the engine requires that the valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leakproof seating. Valve stems must work freely and smoothly within the valve guides and the correct valve clearance must be maintained.

Proper maintenance and operation of the engine is important to long valve life. Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems. Sticking valves may eventually become bent or broken by being held in the open position and struck by the piston. Tightly adjusted valves will cause rapid pitting of the valve seats and a hotter running condition on the valve stems.

Remove Valve Spring (Cylinder Head Installed)

A valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and remove the valve rocker cover.

2. Bar the engine until the number 1 injector follower descends between 3.0-4.0 mm (.120-.160"). The valves will now be in a closed position. The piston is now near the top of its stroke.

> **CAUTION:** Be sure that the injectors are in a no-fuel position before barring the engine as personal injury could result.

> **NOTE:** When a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets, rocker arms and shaft.

4. Thread a suitable tool such as valve spring compressor adaptor tool J 7455 into one of the rocker arm bracket bolt holes in the cylinder head. Then, compress the spring and remove the two-piece valve lock.

5. Release the tool and remove the valve rotator, valve spring and the oil seal. Remove the oil seal with tool J 28612. Discard the oil seal.

6. Repeat Steps 2 thru 5 in firing order sequence to remove the remaining valve springs.

Remove Valves and Valve Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the valves and springs as follows:

1. Place the cylinder head on a cylinder head rollover stand J 33763.

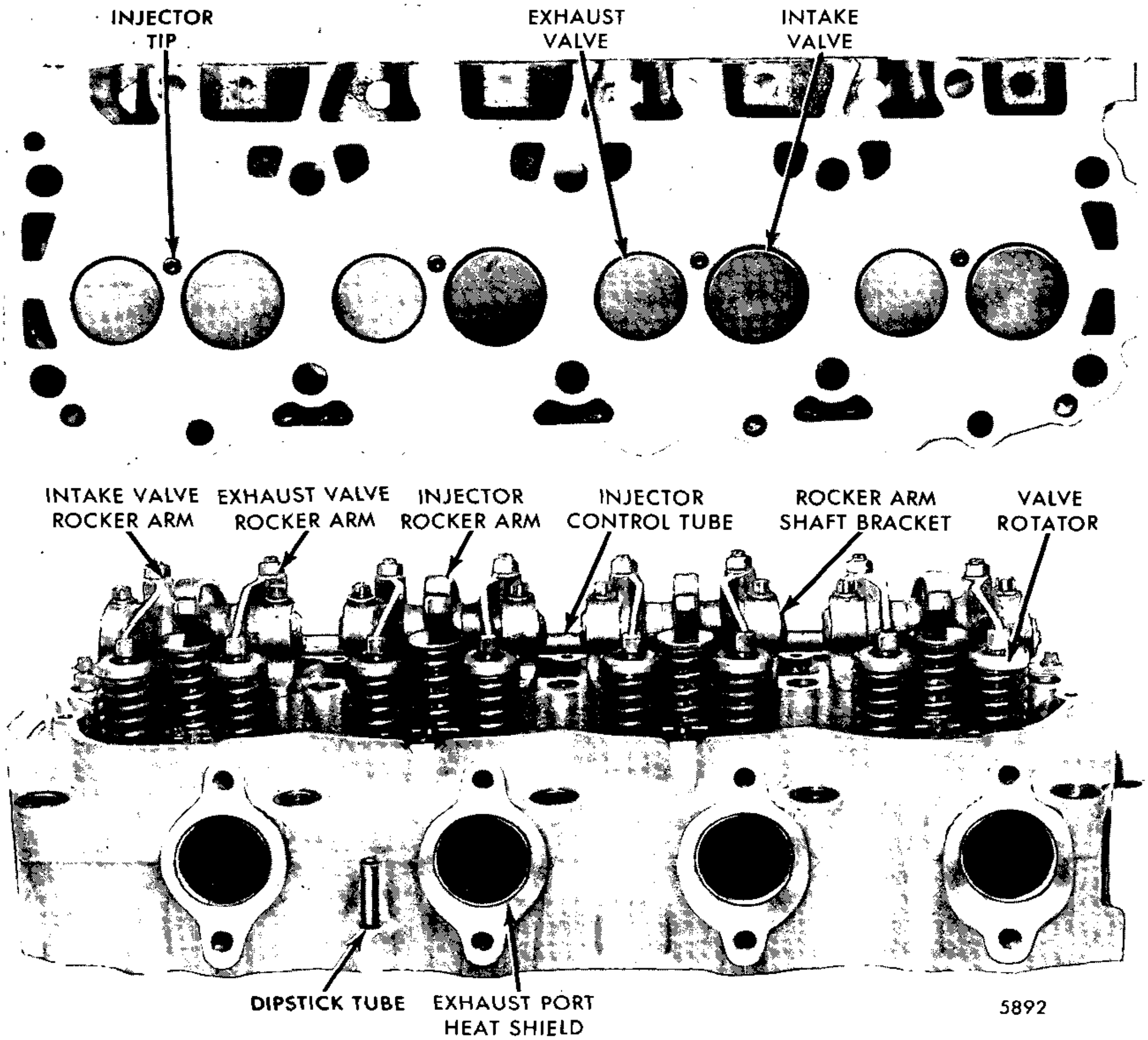


Fig. 1 - Cylinder Head Assembly

2. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets, rocker arms and shaft.

3. Compress the valve springs using valve spring compressor tool J 8062. Remove the two-piece valve lock. Release the tool and remove the valve rotator, valve spring and oil seal. Remove the oil seal with tool J 28612. Discard the oil seal.

4. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate reinstallation in the same location. Then withdraw the valves from the cylinder head.

Inspection

Clean the springs with fuel oil, dry them with compressed air and inspect them. Replace a pitted or fractured spring.

A valve spring that has experienced high stress will generally fracture one and one half coils from the end of the spring. However, the entire spring should be

inspected. Replacement of a broken valve spring requires a new rotator and valve locks. Detroit Diesel Allison recommends that all valve springs, rotators and locks be replaced at the time of major overhaul. Further, these parts should be replaced at the time a major failure has occured after 100,000 miles or 3,000 hours of engine operation.

Use spring tester J 22738-02 to check the spring load (Fig. 2). Replace a spring if a load of less than 177.93 N (40 lbs.) will compress the spring to 50.8 mm (2 inches).

Carbon on the face of a valve indicates blow-by due to a faulty seat. Black carbon deposits extending from the valve seats may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits is evidence of high operating temperatures. High operating temperatures are nórmally due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

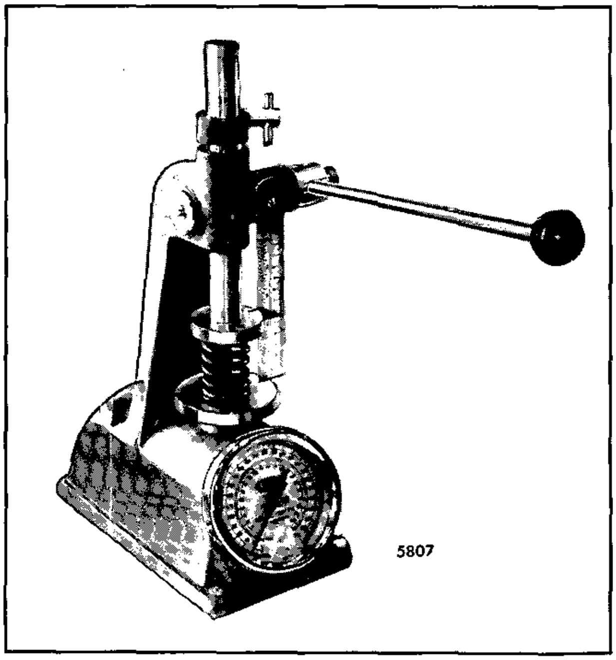


Fig. 2 - Testing Valve Spring

Clean the inside diameter of the valve guide bores with a suitable brush such as J 8101. This brush will remove all gum or carbon deposits from the valve guide bores.

Inspect the valve guide bores for chipping, scoring or excessive wear. Check the valve-to-guide clearance, since worn valve guide bores may eventually result in improper valve seat contact.

The valve stem diameter of a new valve is 8.66-8.68 mm (.341-342"). The maximum allowable wear limit is .04 mm (.002") or a diameter no less than 8.61 mm (.339"). A new valve guide bore diameter is 8.703-8.705 mm (.343-.344"). The maximum allowable wear limit is .127 mm (.005") or a diameter no greater than 8.832 mm (.348").

The combined wear of the valve stem and the valve guide bore should not exceed .127 (.005") clearance on the diameter.

Recondition Valve and Seat

A valve which is to be reused may be refaced, if necessary on a valve grinder such as shown in Fig. 3.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating.

When the valve seat in the cylinder head is to be reground, the work must be done with a suitable grinding wheel.

The eccentric grinding method (tool J 7040) for reconditioning valve seats in the cylinder head is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A

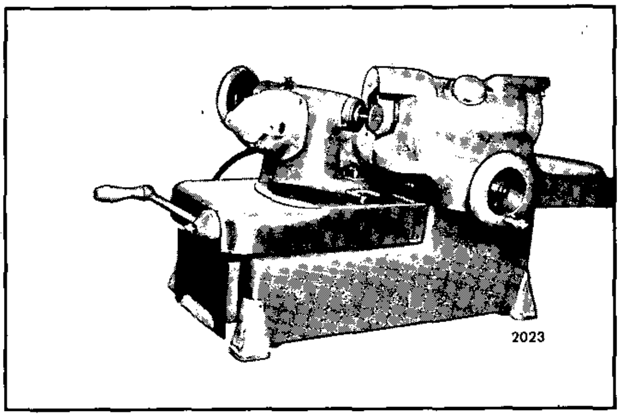


Fig. 3 - Refacing Valve

micrometer feed permits feeding the grinding wheel into the work .025 mm (.001") at a time.

The valve must not protrude beyond the cylinder head (when the valve is in the closed position), to maintain the proper piston-to-valve clearance. Use sled gage J 22273-01 to measure valve position. Grinding the valve seat will cause the valve to recede into the cylinder head.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with a suitable dressing tool provided with the grinder set shown in Fig. 4.

After grinding has been completed, clean the valve seat thoroughly with fuel oil and dry it with compressed air. Set a suitable dial indicator such as J 8165-2 in position in the valve stem guide bore and rotate it to determine the concentricity of each valve seat relative to the valve stem guide bore. If the runout exceeds .05 mm. (.002") regrind the valve seat in the cylinder head.

After the valve seat in the cylinder head has been ground, determine the position of the contact area between the valve and the valve seat as follows:

a. Apply a light coat of Prussian Blue or similar paste to the valve seat.

b. Lower the stem of the valve in the valve bore and "bounce" the valve on the seat. This procedure will show the the area of contact (on the valve face). The contact pattern should cover a full 360° .

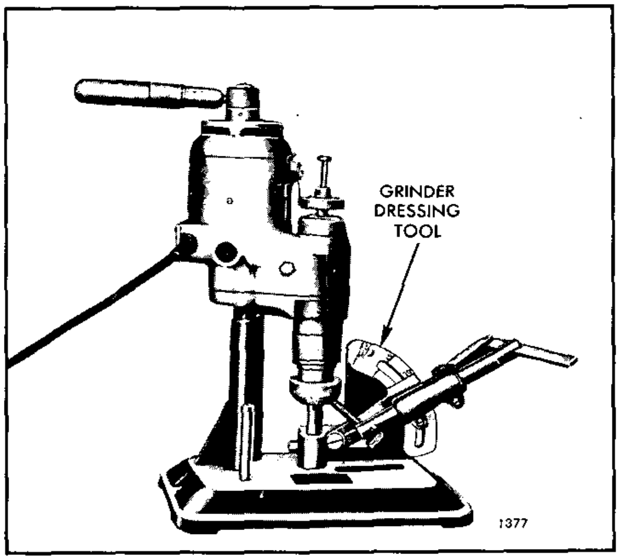


Fig. 4 - Grinding Wheel Dressing Tool

After the valve seats have been ground and checked, thoroughly clean the cylinder head before installing the valves.

Install Valves and Springs

1. Lubricate the valve stems with clean engine oil and slide the valves all the way into the bores.

> **NOTE:** If reconditioned valves are used, install them in the same cylinder location from which they were removed.

2. Hold the valves in place temporarily with a strip of masking tape. Then, turn the cylinder head right side up on the work bench. Place a board under the head to support the valves, or turn the head over using rollover stand J 33703.

3. Refer to Fig. 5 and install the valve oil seals, on the valve guide bores using tool J 28612 as follows:

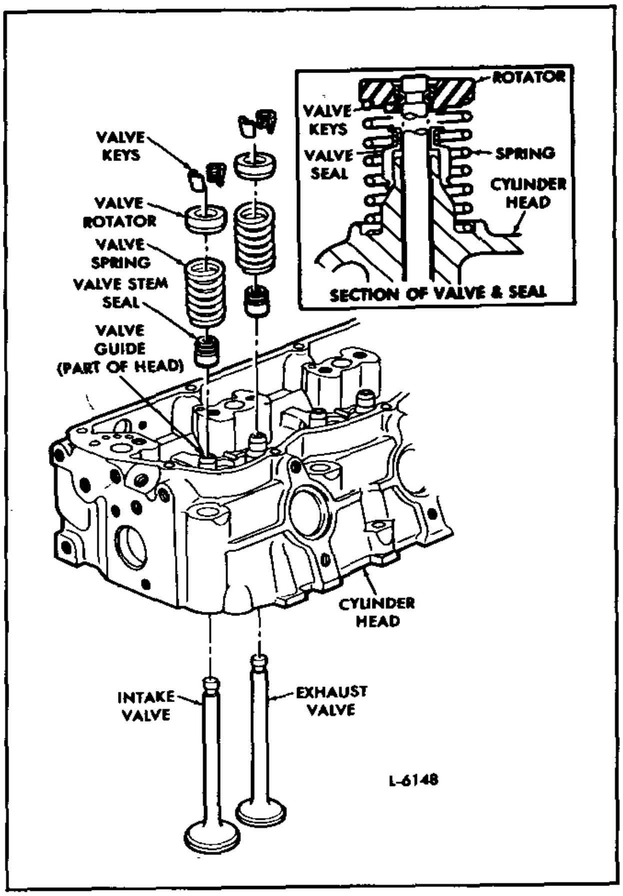


Fig. 5 - Valves and Relative Location of Parts

a. Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16" below the groove on the valve stem, remove the cap and cut off the excess length.

b. Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide bore.

c. Remove the installation cap.

4. Install the valve spring and the valve rotator.

5. Thread a suitable valve spring compressing tool such as J 7455 into one of the rocker shaft bracket bolt holes in the cylinder head.

6. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve rotator when compressing the spring. Give the end of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

NOTE: Compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

7. Release the tool and install the valve locks on the remaining valves in the same manner.

8. With the valves installed in the cylinder head, use a suitable spring checking gage such as J 25076-B to check the amount of pressure before the valve starts to open. The minimum pressure required to start to open the valve must not be less than 222 N (50 pounds).

9. Install the injector, control tube assembly and any other parts that were previously removed from the cylinder head.

10. Install the cylinder head, rocker arms, shafts, brackets and remainder of parts. Refer to Pre-Installation Inspection and Install Cylinder Head in Section 1.2.

11. Initial valve clearance can be set with the engine cold at 0.36 mm (.014") using a feeler gage for exhaust and 0.31 mm (.012") for intake valves.

12. After the engine has been run, perform a complete tune-up as outlined in Section 14.

VALVE ROCKER COVER

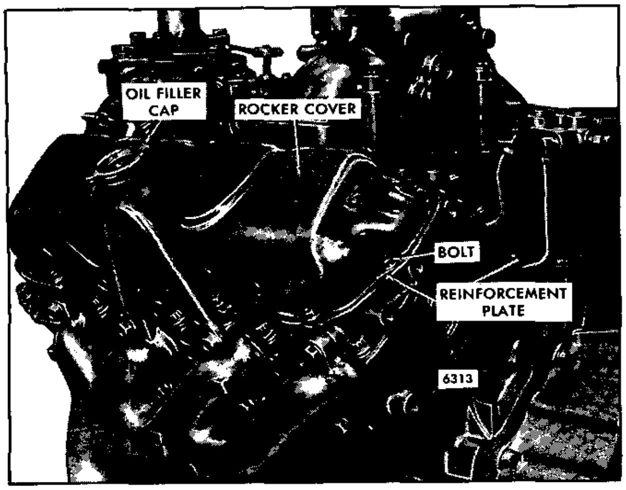


Fig. 1 - Valve Rocker Cover Mounting

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head on each bank. The rocker cover is made of sound damping laminated steel. The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

The valve rocker cover assembly has an oil filler cap on each bank.

Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then remove eleven bolts and reinforcement plates and lift the cover straight up from the cylinder head. Discard the cover gasket.

Thoroughly clean the head and valve rocker cover gasket surface. Apply a bead of Room Temperature Vulcanizer (RTV) sealer or equivalent to the valve rocker cover and install a new gasket. *Then install the* cover assembly. Tighten the cover bolts to 23-27 Nm (17-20 lb-ft) torque.

CRANKSHAFT

The crankshaft (Fig. 1) is a one-piece ductile iron casting with pressure rolled fillets to ensure strength and durability.

The crankshaft end play is controlled by the No. 4 upper main (saddle) bearing, with thrust flanges. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

Eight tapped holes are provided for attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position. This is essential for proper engine balance.

> **NOTE:** Some early built engines had a crankshaft with a larger flywheel retaining bolt hole circle. To eliminate the possibility of rear oil seal leakage caused by crankshaft butt end distortion after the flywheel bolts are tightened, the diameter of the bolt hole circle was reduced from 112.8 mm (4.44") to 106.68 mm (4.20").

Remove Crankshaft

When removal of the crankshaft becomes necessary, separate the transmission from the engine and proceed as follows:

1. Clean the exterior of the engine.

2. Drain the cooling system.

3. Drain the engine crankcase.

4. With a suitable lifting chain hoist and sling attached to the lifter brackets remove all engine mounting bolts and remove the engine from its base.

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting adaptor.

> **CAUTION:** Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan and discard the gaskets.

8. Remove the oil pump inlet pipe and screen assembly.

9. Remove the flywheel and flywheel housing.

10. Remove the crankshaft pulley.

11. Remove the front engine support.

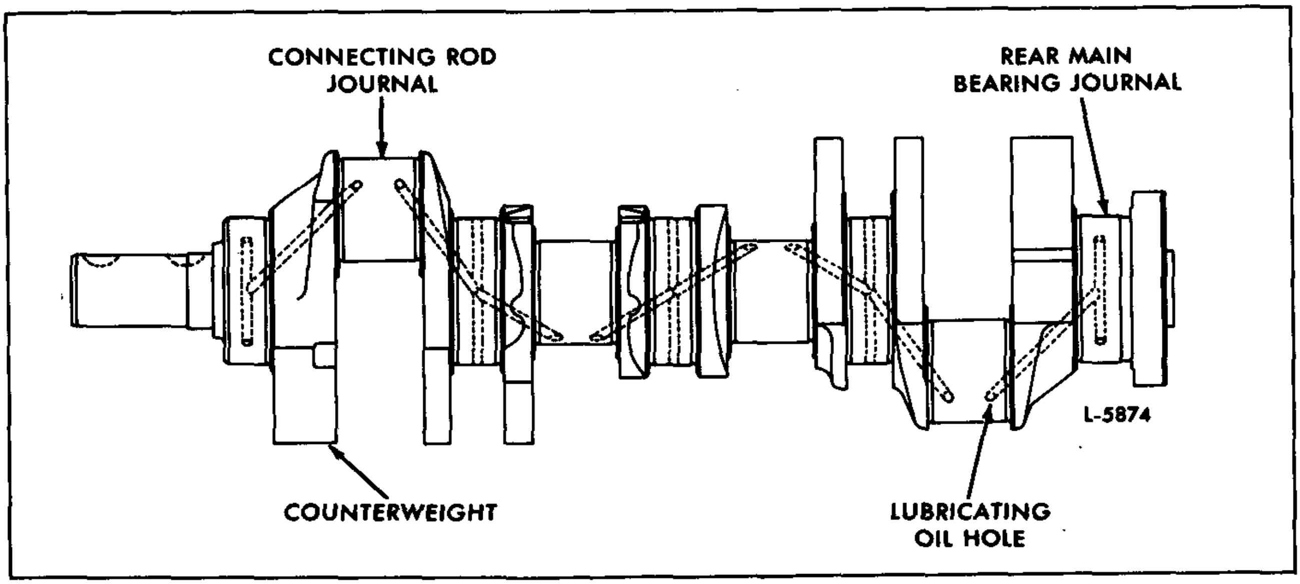


Fig. 1 - Typical Crankshaft

12. Remove the water pump and front cover.

13. Remove the cylinder heads.

14. Remove the connecting rod bearing caps.

15. Remove the piston and connecting rod assemblies.

16. Remove four bolts at each main bearing cap and remove the caps.

17. Remove the crankshaft, as shown in Fig. 2.

18. Refer to Section 1.7.5 for removal of the crankshaft timing gear.

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 3). Ridges exceeding .005 mm (.0002") must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

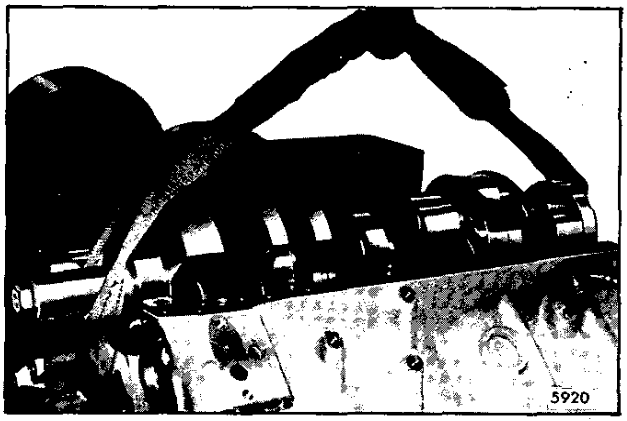


Fig. 2 - Removing Crankshaft

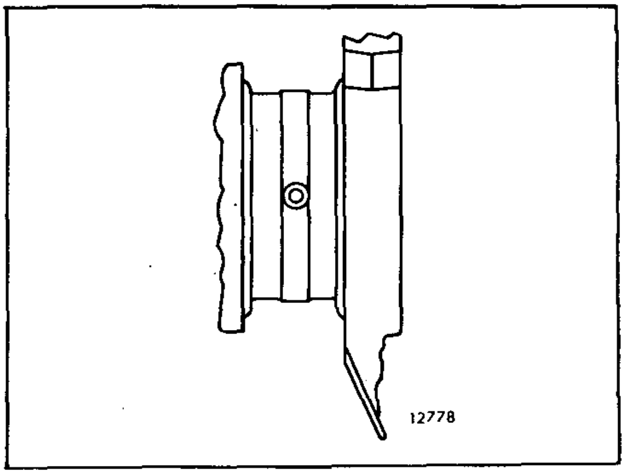


Fig. 3 - Typical Ridging of Crankshaft

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0127 mm (.0005"), first use 120 grit emery cloth to clean up the ridge, then use 240 grit emery cloth for finishing and the wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .025 mm (.001"), the crankshaft will have to be replaced.

Carefully inspect the rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface on the sleeve will result in oil leakage at this point.

Check the crankshaft thrust surfaces (at No. 4 main bearing) for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise it will be necessary to replace the crankshaft.

Check the crankshaft and camshaft gears for worn or chipped teeth. Replace the gears, if necessary.

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks or in a lathe and check the alignment at the adjacent intermediate main journals with a dial indicator.

Measure all of the main and connecting rod bearing

journals. Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal-to-bearing shell clearance (with new shells) exceeds .127 mm (.005") or the main bearing journal-to-bearing shell clearance (with new shells) exceeds .142 mm (.0056"), the crankshaft must be replaced.

Measurements of the crankshaft should be accurate to the nearest .0051 mm (.0002"). Also, if the journal taper or out-of-round is greater than .076 mm (.003"), the crankshaft must be replaced.

Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be de-magnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employes magnetic particles which are fluorescent and glow under "black light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the black light.

Fluorescent Penetrant Method: This is a method which may be used on non-magnetic materials such as stainless steel, aluminum and plastics. A highly fluorescent liquid penetrant is applied to the part. Then the excess penetrant is wiped off and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "black light".

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impared when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service, a bending force and a twisting force. The design of the shaft is such that these forces produce very low no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load.

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution. The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced crankshaft pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency and can

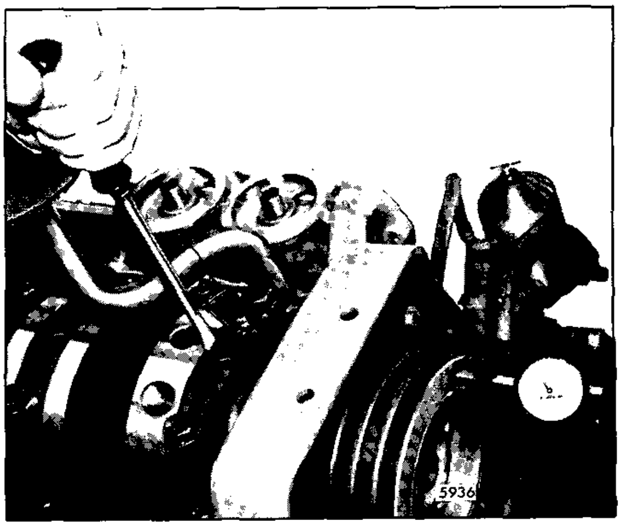


Fig. 4 - Checking Crankshaft End Thrust

be caused by a damaged vibration damper or an unbalanced load. A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, which imposes high stress.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes. Replace the crankshaft when cracks of this nature are found.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive and blow out oil passages with compressed air. Then install the crankshaft as follows:

1. Assemble the crankshaft gear on the front of the crankshaft.

2. Refer to Section 1.3.4 for main bearing details and install the upper grooved bearing shells in the block. The number 4 main saddle bearing also serves as the thrust bearing. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

   NOTE: When a new crankshaft is installed ALL new main and connecting rod (upper and lower) bearing shells must also be installed.

3. Apply clean engine oil to all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft gear and the camshaft gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

4. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearings caps from which they were removed.

   NOTE: Whenever a new cylinder block, crankshaft, camshaft or timing gear is installed, any previously determined injector timing heights are no longer valid. New base circle timing heights must be established by precision timing the engine.

5. Install the main bearing caps and lower bearing shells as outlined under INSTALL MAIN BEARING SHELLS in Section 1.3.4.

   NOTE: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

6. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 4) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be .19 mm to .38 mm (.007" to .015") with new parts. Insufficient end play can be the result of a burr or dirt on the inner face of the thrust bearing.

7. Check the gear backlash with the mating gear. The backlash should be 0.0762-0.1778 mm (0.003-0.007") with new gears or 0.2286 mm (0.009") maximum with used gears.

8. Install the pistons and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder heads (refer to Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).

11. Install the front end cover.

12. Install the front engine support.

13. Install the crankshaft pulley.

14. Install the water pump assembly on the upper front cover.

15. Install the oil pump inlet pipe and screen assembly.

16. Affix new gaskets to the oil pan flange and install the oil pan (Section 4.7).

17. Attach the lifting device to the lifting brackets and remove the engine from the overhaul stand.

18. Install all of the accessories that were removed.

19. After the engine has been completely reassembled, refer to the Lubrication Oil Specifications in Section 13.3 and refill the crankcase to proper level on the dipstick.

20. Close any coolant drains. Install new drain plugs in both banks of the block, remount the engine and fill the cooling system.

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the engine to retain the lubricating oil in the crankcase. The front crankshaft seal is a single lip seal and is pressed into the front cover. The seal is held firmly against the hub of the crankshaft pulley.

The rear crankshaft seal is a single lip seal and is pressed into the flywheel housing. The seal is held firmly against the rear sealing surface of the crankshaft.

The oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. DO NOT REMOVE THIS LUBRICANT. Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the seal casing. Do not remove this coating.

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearance, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft or front pulley seal hub. Prior to repair of any oil seal leaks, these conditions must be checked and corrected.

Remove Front Crankshaft Seal

If the front cover is installed on the engine, remove the seal as follows:

1. If the engine is in the chassis, loosen and remove all drive belts.

2. Remove the crankshaft pulley (refer to Section 1.3.7).

3. Remove the front crankshaft seal, usng tool J 29007-A. Discard the oil seal.

If the front cover is removed from the engine, remove the seal as follows:

1. Support the forward face of the front cover on two wood blocks next to the oil seal bore. Then press the oil seal out of the front cover, using tool J 29008-B. Discard the oil seal.

2. Clean the oil seal bore in the front cover thoroughly before installing a new oil seal.

Inspection

Inspect the crankshaft pulley sealing surface for wear due to the rubbing action of the oil seal, dirt buildup or fretting caused by action of the crankshaft pulley.

The crankshaft pulley sealing surface must be clean and smooth to prevent damage to the seal lip when a new oil seal is installed.

If excessive wear or grooving is present, the seal should be relocated in the front cover away from the worn or grooved area.

Install Front Crankshaft Seal

Coat the lip of the new oil seal lightly with clean engine oil or grease. Then position the seal in the front cover bore with the lip of the seal pointed toward the inner face of the cover.

If the front cover is installed on the engine, install the seal as follows:

1. Using seal installer J 29008-B, pull the seal into the front cover until the tool contacts the cover.

2. If an alternate seal location is selected due to wear or grooving of the crankshaft pulley sealing surface, the seal is to be installed using J 29008-B (installer) and J 29008-5 (alternate location adaptor) as shown in Fig. 1.

3. Install the adaptor J 29008-5 on J 29008-B and pull the seal into the front cover until the tool contacts the cover.

4. Reinstall the crankshaft pulley (refer to Section 1.3.7).

5. Reinstall and tighten the drive belts following the manufacturers recommendations.

If the front cover is removed from the engine, install the seal as follows:

1. Place the front cover in an arbor press (inner face down).

2. Using J 29008-B (seal installer) press the seal into the cover until the tool contacts the cover.

3. If the alternate seal location is selected due to wear or grooving of the crankshaft pulley sealing surface,

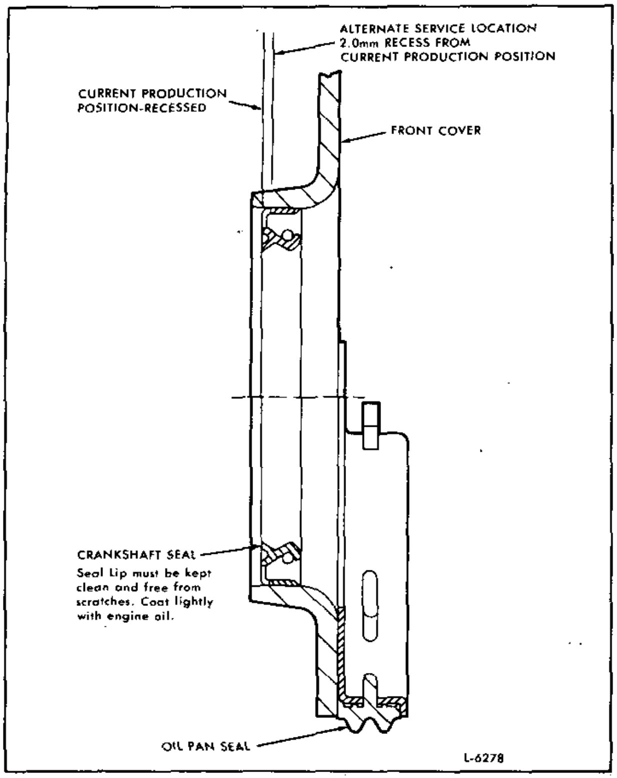


Fig. 1 - Locations for Front Crankshaft Seal

the seal is to be installed using J 29008-B and J 29008-5 (alternate adaptor) (see Fig. 1).

4. Install the adaptors J 29008-5 on J 29008-B and press the seal into the front cover until the tool contacts the cover.

Remove Rear Crankshaft Seal

If the flywheel housing is installed on the engine, remove the seal as follows:

1. If the engine is in the chassis, remove the transmission.

2. Remove the flywheel (refer to Section 1.4).

3. Using tool J 24171 (Universal Seal Remover) remove the oil seal. Discard the oil seal.

If the flywheel housing is removed from the engine, remove the seal as follows:

1. Support the rear face of the flywheel housing on two wood blocks then press or drive the oil seal out of the housing. Discard the oil seal.

2. Clean the oil seal bore in the flywheel housing thoroughly before installing a new oil seal.

Inspection

Inspect the rear end of the crankshaft for wear due to the rubbing action of the oil seal, dirt buildup or fretting caused by action of the flywheel.

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed.

If excessive rear crankshaft wear or grooving is present, install an oversize oil seal sleeve which provides a replaceable wear surface for the lip type oil seal. An oversize oil seal must be used with the sleeve.

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off the end of the crankshaft.

Install Rear Oil Seal Sleeve

If required, install a rear oil sleeve as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Drive the sleeve squarely on the shaft with sleeve installer J 33426.

4. Wipe off any excess sealant.

5. Coat the outside diameter of the sleeve with engine oil.

Install Rear Crankshaft Seal

If the flywheel is installed on the engine, install the seal as follows:

1. Place oil seal expander J 29009-A against the end of the crankshaft and install two suitable mounting studs.

2. Coat the lip of the oil seal lightly with clean engine oil or grease. Do not scratch or nick the sealing edge of the oil seal.

3. Position the seal with the lip pointed toward the flywheel housing and slide the seal over the seal expander onto the crankshaft.

4. Remove J 29009-A (seal expander) and two mounting studs.

5. Using J 29010-A (installer) and J 3154-1 (handle) drive the seal in until the tool bottoms against the flywheel housing.

6. When a rear crankshaft sleeve has been installed, it will be necessary to install an oversize oil seal. Use J 33873 (oversize oil seal expander), J 29010-A (installer) and J 3154-1 (handle).

7. Reinstall the flywheel (refer to Section 1.4).

8. If the engine is in the chassis, reinstall the transmission.

If the flywheel housing is removed from the engine, install the seal as follows:

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.

2. Position the seal with the lip pointed toward the inner face of the housing.

3. Coat the lip of the oil seal lightly with clean engine oil or grease. Do not scratch or nick the sealing edge of the oil seal.

4. Use installer tool J 29010-A and handle J 3154-1 and drive or press the seal until the tool bottoms against the flywheel housing.

5. When a rear crankshaft sleeve has been installed, it will be necessary to install an oversize oil seal. Use J 29010-A (installer) and J 3154-1 (handle).

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support (Fig. 1). The number (4) main bearing (upper) is different. It has the thrust washers built into it. A lower bearing shell is seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

An oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with an oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rod bearing. The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

Main bearing trouble is ordinarily indicated by low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower main bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

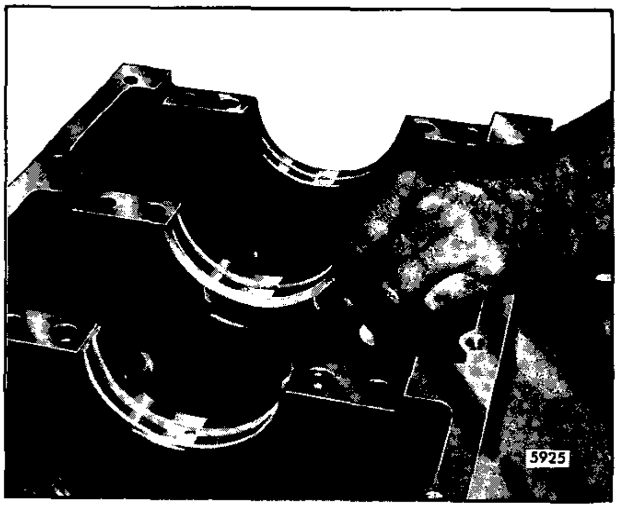


Fig. 1 - Upper Main Bearings

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.

2. Remove the oil inlet pipe and screen assembly.

3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under INSPECTION. Reinstall each bearing shell and bearing cap before removing another bearing cap.

To remove the upper bearing shell, insert a flattened cotter pin or roll pin in the oil passage hole in the crankshaft, then rotate the crankshaft in the direction opposite to cranking rotation. The pin will contact the upper shell and roll it out.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low or no oil.

Check the oil filters and replace them if necessary. Also check the oil by-pass valve to make sure it is operating freely. Check the oil cooler for debris (Section 4.4).

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbit or signs of overheating. The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells as shown in Fig. 2. A tool such as J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement.

The bearing shell thickness will be the total thickness

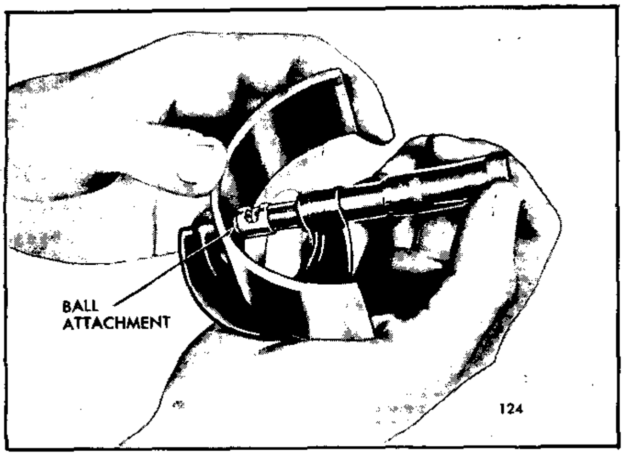


Fig. 2 - Measuring Thickness of Bearing Shell

of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is 3.137 mm (.124") and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of 3.175 mm to 3.188 mm (.125" to .1255").

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing. With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .025 mm (.001") larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This CRUSH assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform seat contact, as shown by shiny spots on the back, and must be replaced. The main bearing clearance must not exceed .142 mm (.0056") on all bearings.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatique and resultant cracks in the crankshaft. Refer to Section 1.3 under Crankshaft Inspection for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new crankshaft is to be used, install all new bearing shells.

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication--the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearing will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

Fig. 3 - Tightening Bearing Cap Bolts

NOTE: The number 4 upper main bearing **only** incorporates the thrust surfaces.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

2. Install the lower bearing shell so that the tang on the bearing sits into the groove in the bearing cap.

NOTE: The main bearing caps are bored in position. If not stamped, stamp the main bearing caps 1, 2, 3, etc. Start at the front of the engine. They must be installed in their original positions.

3. With the lower main bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact area. Install the bearing caps and draw the bolts up snug (Fig. 3). Then rap the caps *sharply with a soft hammer to seat them properly.* Tighten the main bearing cap bolts to 90-103 Nm (66-76 lb-ft) (outboard bolts) and 140-160 Nm (103-118 lb-ft) torque (inboard bolts).

NOTE: If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

4. Check the crankshaft end play outlined under "Install Crankshaft" in Section 1.3.

5. Install the oil pump inlet pipe and screen assembly.

6. Install the oil pan using new gaskets. Use R.T.V. sealer at all gasket joint connections.

7. Fill the crankcase to the proper level on the dipstick. Refer to Lubricating Oil Specifications in Section 13.3.

FRONT COVER

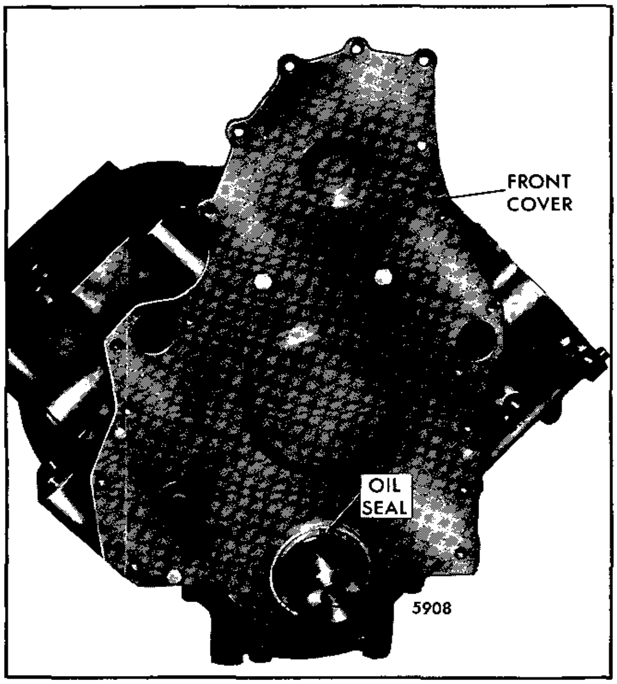


Fig. 1 Engine Front Cover

A flat steel plate, Fig. 1 bolted to the front end of the cylinder block, provides support for the water pump. The front crank oil seal is pressed into the front cover.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and cylinder block. Clean the end plate with live steam.

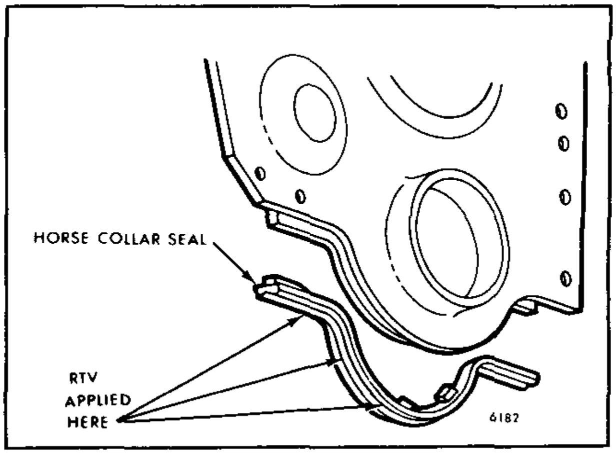


Fig. 2 - Installing Horse Collar Oil Pan Seal

Inspect both surfaces of the end plate for nicks, dents, scratches or score marks and check it for warpage. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, replace the end plate.

Install Cover

1. Affix a new gasket to the front end of the cylinder block, using Room Temperature Vulcanizer (RTV) sealant or equivalant.

2. Align the dowel pin holes in the end plate with the dowel pins in the cylinder block. Then start the end plate over the dowel pins and push it up against the cylinder block. Install three bolts and tighten them to 30-34 Nm (22-25 lb-ft) torque.

3. Apply Room Temperature Vulcanizer (RTV) and install horse collar oil pan seal (Fig. 2).

CRANKSHAFT PULLEY AND DAMPER ASSEMBLY

The crankshaft pulley (Fig. 1) is secured to the front end of the crankshaft. It is a press fit on the shaft. It is keyed and attached by a special washer and bolt. The hub on the pulley revolves inside of the front cover oil seal. It serves as the sealing surface for the front crankshaft oil seal.

Remove Crankshaft Pulley

Remove all drive belts from the crankshaft pulley.

An excessively tight fit between the crankshaft pulley bore and the washer may impede the removal of the crankshaft pulley after the center bolt has been removed.

Tool set J 29025 is designed to remove the pulley by pressing against the crankshaft end. For the lead screw of the puller to press against the front of the crankshaft, the washer must be removed.

If the washer cannot be removed, it may be necessary to use a M20 x 2.5 x 90 mm bolt. The bolt head must be center drilled to accept the point, of the lead screw, of the puller.

1. Remove the crankshaft pulley retaining bolt.

2. Thread the (center drilled) bolt through the washer into the crankshaft.

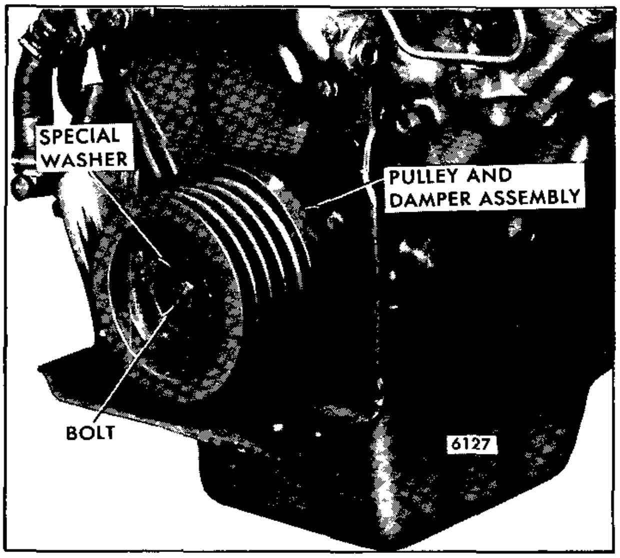


Fig. 1 - Pulley and Damper Assembly

3. Attach the puller tool to the pulley and damper with 3/8"-16 bolts.

4. Press against the center drilled head of the bolt with the lead screw of the puller. This procedure will pull the pulley and washer off of the crankshaft.

6. Remove the puller tool from the crankshaft pulley.

> ***NOTE:*** *The special washer on the crankshaft* pulley damper assembly is designed to assist in preventing oil leakage from the crankshaft keyway. It is important that this washer be flat, if it is not, oil seepage is possible. If on inspection the washer is found to be bowed it should be trued by machining or on a surface block, or it should be discarded and a new washer fitted.

Install Crankshaft Pulley

1. Apply a suitable sealer to the inside diameter of the pulley hub and to the crankshaft key to prevent possible oil leakage. Coat the outside of the crankshaft pulley hub which enters the seal with a seal lubricant.

2. Start the pulley straight on and over the key in the end of the crankshaft. Use tool J 29025 to draw the pulley on the crankshaft. Remove the tool.

> **NOTE:** The crankshaft pulley and damper retaining bolt is especially designed for this purpose and **must not** be replaced by an ordinary bolt.

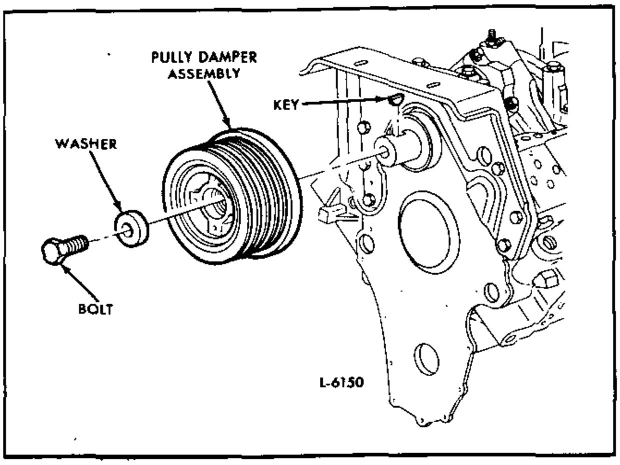


Fig. 2 - Crankshaft Pulley Details

3. Place the washer on the crankshaft pulley bolt and thread the bolt into the front end of the crankshaft.

4. Tighten the crankshaft pulley retaining bolt to 334-384 Nm (246-283 lb-ft) torque.

5. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with eight bolts. A misaligned hole in the flywheel must mate with a misaligned hole in the crankshaft and plate for proper installation. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch. The clutch plate is bolted to the flywheel with 3/8"-16 bolts.

The front side of the flywheel has four equally spaced timing pin holes. These are locator holes for use in timing the injectors.

Remove Flywheel (Transmission Removed)

On marine engines, first remove the flywheel housing adaptor cover (refer to Section 1.5).

1. Remove the flywheel attaching bolts and the scuff plate while holding the flywheel in position by hand, then reinstall one bolt finger tight.

NOTICE: When removing or installing the attaching bolts, hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft.

2. Use a suitable lifting tool to remove the flywheel (Fig. 1).

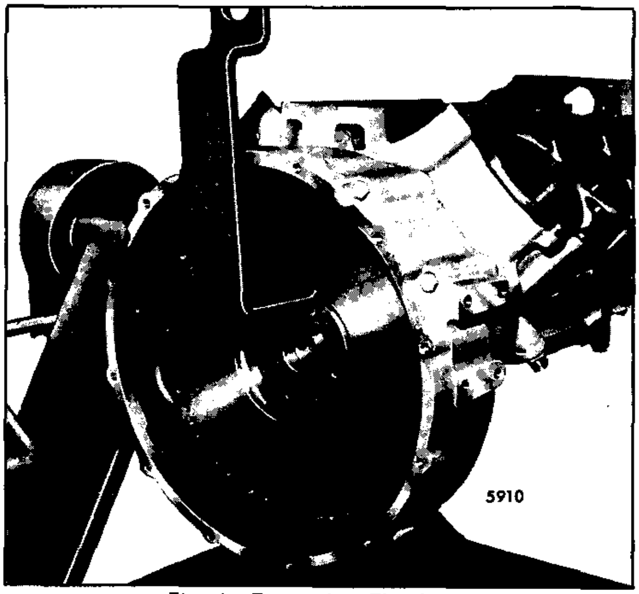


Fig. 1 - Removing Flywheel

3. Attach a chain hoist to the lifting tool.
4. Remove the remaining flywheel attaching bolt.
5. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, DO NOT remove more than .50 mm (.020") of metal from the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged.

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal-to-metal contact and maximum friction, before attaching the flywheel.

NOTICE: New patch bolts must be used to mount or remount the flywheel assembly. Also, the scuff plate must be inspected for cracks and other damage. Replace scuff plate if found to be damaged.

Remove Ring Gear

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.
2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.
2. Rest the ring gear on a flat METAL SURFACE and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

NOTICE: Do not under any circumstances, heat the gear over 204°C (399°F); excessive heat may destroy the original heat treatment. Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

CAUTION: To avoid personal injury, use lifting tools or heat resistant gloves when placing the HEATED ring gear on the flywheel.

3. Place the HEATED ring gear on the flywheel with the larger leading 45° chamfer facing the flywheel shoulder.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above note.

Install Flywheel

1. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs). A misaligned hole in the flywheel must mate with the misaligned hole in the crankshaft and scuff plate for proper installation.
2. Install two used bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.
3. Remove the flywheel lifting tool.
4. Install new bolts and run them in snug.
5. Remove the two bolts used temporarily to retain the flywheel. Then, install two new bolts.
6. Use an accurately calibrated torque wrench and tighten the bolts to 87-100 N·m (64-74 lb-ft) torque.
7. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .025 mm (.001") total indicator reading per inch of radius (or .001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

On marine engines, install the flywheel housing adaptor cover with 11 bolts. Torque the bolts to 46-53 N·m (34-39 lb-ft).

FLYWHEEL HOUSING

The flywheel housing is a one-piece casting, mounted against the rear of the cylinder block. It provides a cover for the flywheel and serves as a support for the starting motor and the transmission. The timing pin guide hole is also located in the front lower section of the housing.

The crankshaft rear oil seal, which is pressed into the housing may be removed or installed without removing the housing refer to Section 1.3.2. On marine engines, it is necessary to remove the flywheel housing adaptor cover.

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Section 1.1.
2. Remove the starting motor from the flywheel housing. On marine engines, remove the flywheel housing adaptor cover (Fig. 1).

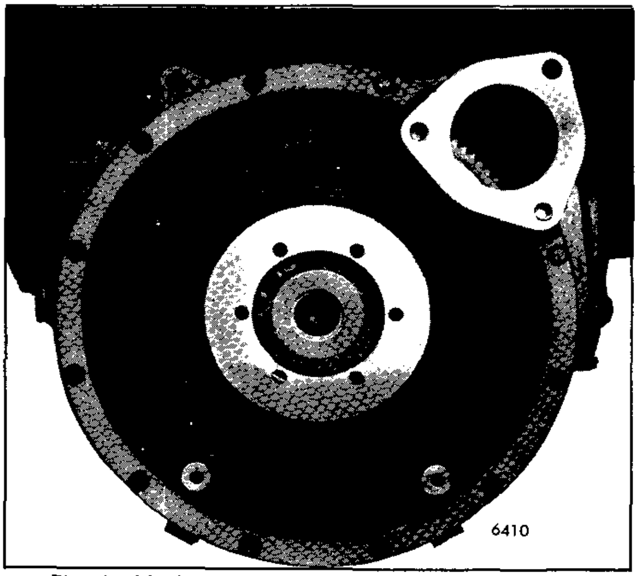


Fig. 1 - Marine Flywheel Housing Adaptor Cover

3. Remove the flywheel and scuff plate.
4. Remove six oil pan to flywheel housing bolts and all of the flywheel housing to block bolts.

NOTICE: When removing the flywheel housing bolts, note the location of the various size bolts so they may be reinstalled in their proper location.

5. To guide the flywheel housing until it clears the end of the crankshaft, thread two suitable pilot studs into the cylinder block.
6. Thread eyebolts into the tapped holes in the side pads of the flywheel housing. Attach a suitable sling to the eyebolts. Then, strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

It is very important that all old sealing material be thoroughly removed from the flywheel housing and the block and oil pan, otherwise runout of the pilot and face of the housing may be affected when the flywheel housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Section 1.3.2.

Install Flywheel Housing

1. Coat the flywheel housing to cylinder block sealing surface with a suitable sealant.
2. Coat the lip of the crankshaft oil seal lightly with engine oil. Do not scratch or nick the sealing edge of the oil seal.
3. To pilot the oil seal on the crankshaft successfully, use oil seal expander J 29009-A. Thread two suitable aligning studs into the cylinder block to guide the housing in place.
4. With the housing suitably supported, position it over the crankshaft and up against the cylinder block. Remove the oil seal expander.
5. Install all of the housing bolts in their proper location, finger tight (Fig. 2). Remove the pilot studs. See Fig. 3 for marine flywheel housing.

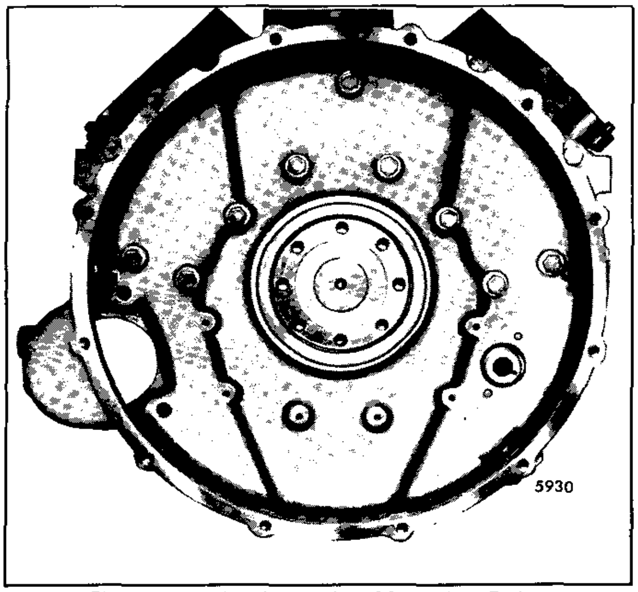


Fig. 2 - Flywheel Housing Mounting Bolts

Tighten the four long outer housing to cylinder block bolts to 46-53 N·m (34-39 lb-ft) torque. Tighten all the other nine housing to block bolts (inside bell housing) to 58-66 N·m (43-49 lb-ft) torque. Tighten the six oil pan to housing bolts. The marine flywheel

housing has 13 bolts (4 long, 9 short). Torque the bolts to 46-53 N·m (34-39 lb-ft).

6. Install the flywheel (Section 1.4).
7. Check the flywheel housing bore concentricity and bolting flange face run-out with Tool J 9737-C as follows:
   a. Thread the adaptor J 9737-10 into one of the tapped holes on the outer edge of the flywheel. Thread the base post J 9737-3 into the adaptor. Then, assemble the dial indicators on the base post (Fig. 4).
   b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.
   c. Tap the front end of the crankshaft with a soft hammer or pry it toward one end of the block to ensure end play is in one direction only.
   d. Adjust each dial indicator to read zero at the twelve o'clock position. Then, rotate the crankshaft one full revolution, taking readings at 45° intervals (8 readings each for the bore and the bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .33 mm (.013") for either the bore or the face.
   e. If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material between the flywheel housing and the cylinder block or oil pan.
   f. Reinstall the flywheel housing (Fig. 2) and the flywheel and tighten the attaching bolts to the specified torque. Then, recheck the runout. If necessary, replace the flywheel housing.
   g. On marine engines, install the flywheel housing adaptor cover. Torque the bolts to 46-53 N·m (34-39 lb-ft). Install the starting motor (Section 7.3).

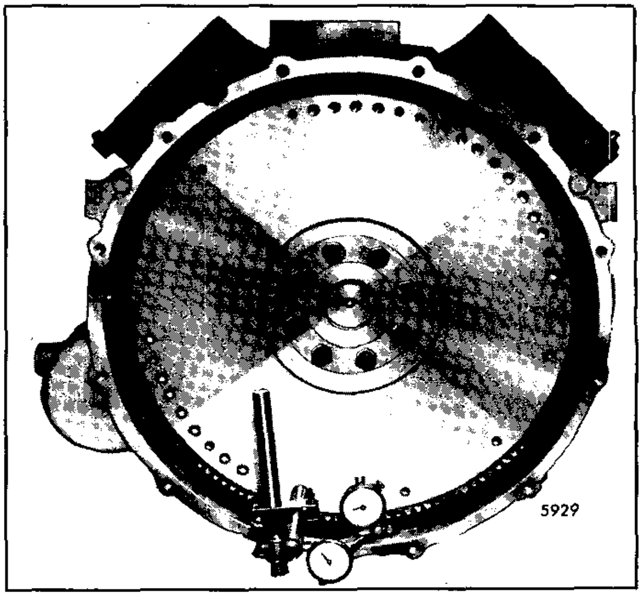
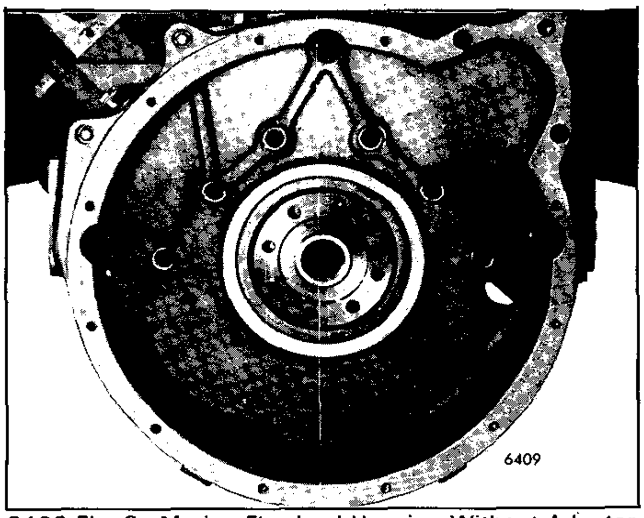


Fig. 4 - Checking Housing Concentricity



6409 Fig. 3 - Marine Flywheel Housing Without Adaptor Cover

Remove the engine from the overhaul stand and complete assembly of the engine.

PISTON AND PISTON RINGS

The piston is plated with a protective coating of tin which permits close fitting, reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress, the air into close proximity, to the fuel spray (Fig. 1).

Each piston is internally braced and scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil. Each piston is balanced to close limits.

The piston pin rides in the machined pin holes in the piston. The piston pin is held in position by a retainer ring at each end.

Each piston is fitted with compression rings and oil control rings.

Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications.

Remove Piston and Connecting Rod

1. Drain the cooling system.

2. Drain the oil and remove the oil pan and inlet pipe assembly.

3. *Remove the cylinder head(s).*

> **NOTE:** Stamp the cylinder number on the machined surfaces of the bolt bosses of the connecting rod and cap for identification when reinstalling. If the pistons are to be removed from the connecting rod, mark cylinder number on piston with a silver pencil or quick drying paint for proper cylinder identification and cap for rod location. The right bank is numbered 2-4-6-8, left bank 1-3-5-7.

4. Examine the cylinder bore above ring travel. If a *ridge exists, remove the ridge with a ridge reamer* J 24270 before attempting to remove the piston and rod assembly.

5. Remove rod bearing bolt, cap and bearing.

6. Remove the rod and piston assembly through the top of the cylinder bore.

7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

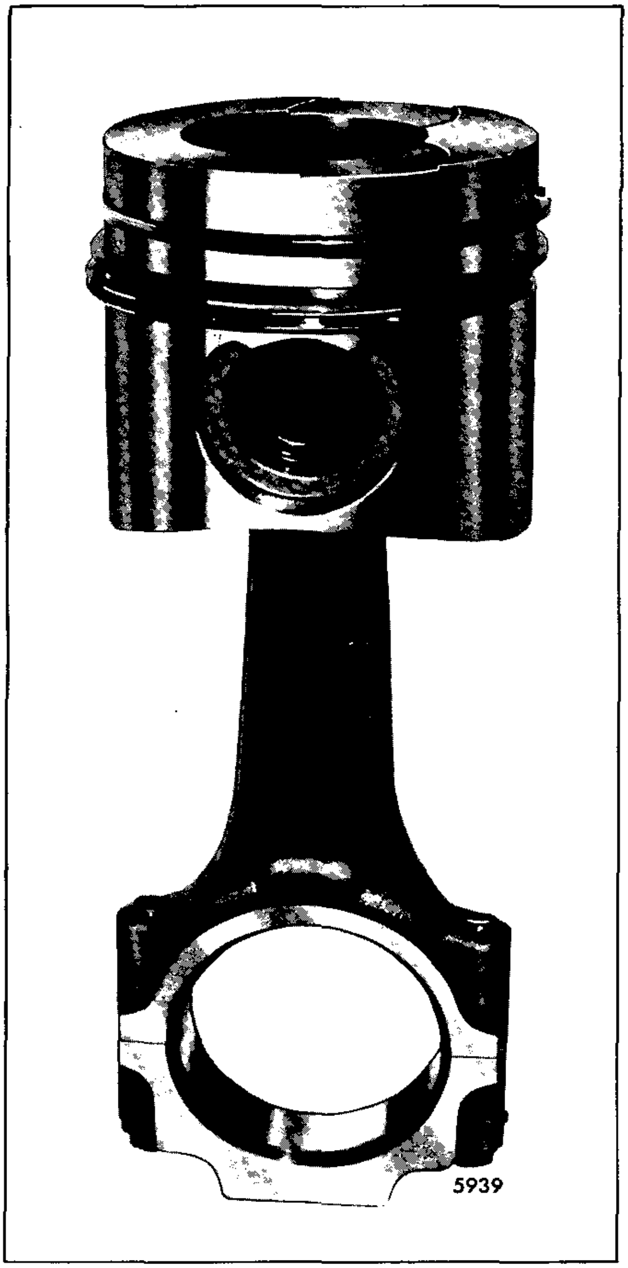


Fig. 1 - Piston and Rod Assembly

8. Remove the other rod and piston assemblies in the same manner.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128.

2. Use suitable tru-arc snap ring pliers and remove the snap ring retaining the piston pin.

3. Remove the piston pin and lift the piston from the connecting rod. Remove the other retaining snap ring.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air. If necessary, clean the pistons by scraping carbon off the top of the piston. Deposits in the ring grooves should be removed with a suitable ring groove cleaning tool or a piece of an old compression ring that has been ground to a bevel edge.

Inspection

Excessively worn or scored pistons, rings or cylinder walls may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct type and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine. Refer to Section 13.3.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which may be cleaned up may be reused. Any piston that has been severely scored or overheated must be replaced.

Replace the piston if cracks are found across the internal struts.

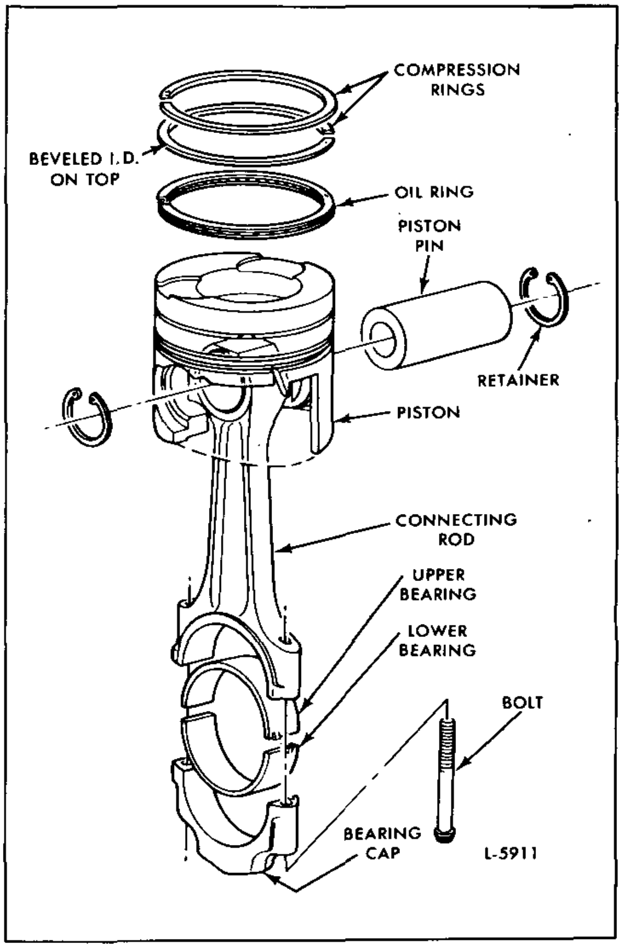


Fig. 2 - Piston Details and Relative Location of Parts

Check the cylinder bores for excessive out-of-round taper or high spots which could cause failure of the piston.

Other factors that may contribute to piston failure include dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Check Bore

Cylinder bore size can be measured with a cylinder bore dial indicator gage J 5347-01. Maximum allowable taper of the cylinder bore .03 mm (.001"). The most wear will occur at the top of the ring travel.

Reconditioned cylinder bores should be held to not more than .0025 mm (.001") out-of-round and .0025 mm (.001") taper.

If the cylinder bores are smooth, the cylinder walls

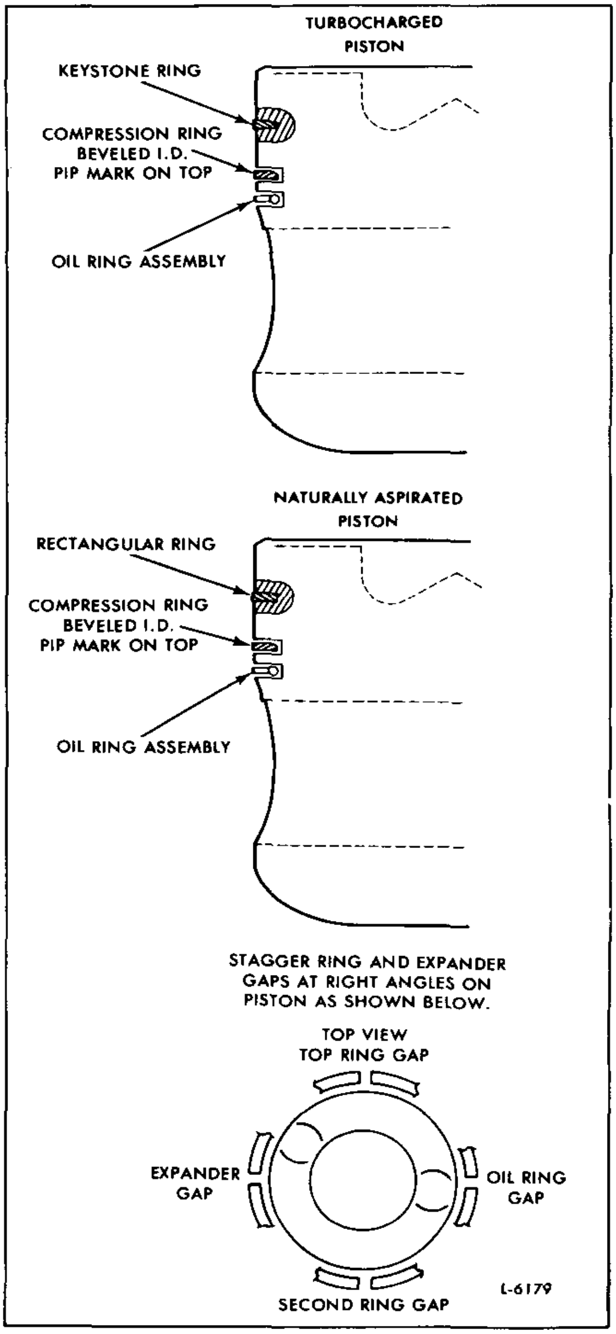


Fig. 3 - Installing Rings on Piston

should not be deglazed. If the cylinder walls are scored, the walls may have to be honed before installing new rings. It is important that reconditioned cylinder bores be thoroughly washed with a soap and water solution to remove all traces of abrasive material

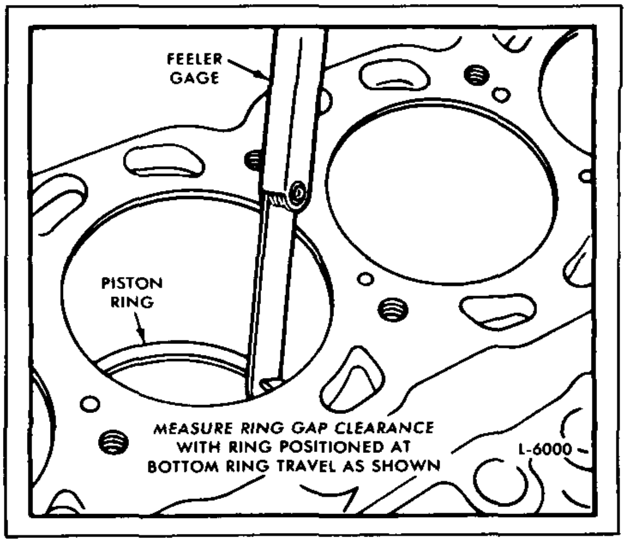


Fig. 4 - Measuring Piston Ring Gap

to eliminate premature wear. Then coat the cylinder walls with oil.

Fitting and Installing Piston Rings

The pistons have three rings (two compression rings and one oil ring - Figs. 2 and 3). The top compression ring used in turbocharged engines has a keystone fire ring. The top ring used in the NA engines is a rectangular ring. The second compression ring used in NA and turbocharged engines is also a rectangular ring, identified by a bevel on the top ID surface. This second ring may or may not have the face chrome flashed. It must be installed with the pip mark and the inside beveled edge toward the top of the engine.

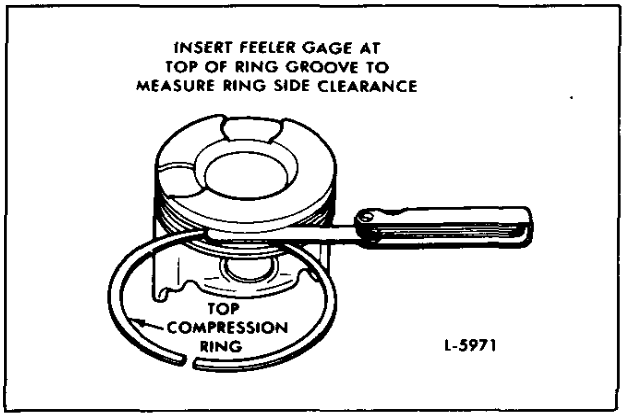


Fig. 5 - Measuring Piston Ring Side Clearance

When installing new rings; check the side clearance and gap using feeler gage J 9708-01 as follows:

1. Measure each ring and rail gap with the ring or rail positioned squarely and at the bottom of the ring travel area of the cylinder bore (Fig. 4).

2. The end gap measurement is .25-.66 mm (.010-.026") for the compression rings.

3. The end gap measurement is .25-.66 mm (.010-.026") for the oil rings.

4. Each compression ring must be checked for side clearance in its respective groove by inserting the feeler gage between the ring and its upper land (Fig. 5). The piston grooves must be cleaned before checking ring for side clearance.

5. The top compression ring (keystone ring on turbocharged engine) side clearance is .06-.14 mm (.0027-.0055"). The lower ring side clearance is .05-.09 mm (.002-.0035").

6. To check the oil ring side clearance, install the oil rings on the piston (Fig. 3). The oil scraper ring side clearance is .05-.08 mm (.002-.0033").

7. Install the compression rings on the piston (Fig. 3).

Install Rod and Piston

1. With the ring gaps staggered (Fig. 3), apply engine oil to the rings and piston. Then install the piston ring compressing tool J 29614 on the piston.

2. Install each piston and rod in its respective cylinder bore so the valve depression in top of the piston is toward the outboard side of the cylinder block.

3. Lubricate the crankshaft journal with engine oil and install the connecting rod bearing, and cap, with the bearing index tang in the rod and cap on the same side.

CONNECTING ROD

Each connecting rod is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end (Fig. 1). A piston pin bushing is pressed into the connecting rod at the upper end. A hole in the upper end of the rod registers with a hole in the bushing. Through this hole, splash oil lubricates the piston pin.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in Section 1.6.

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the oil hole in the upper rod and bushing.

Visually check the connecting rod for twist or bending. Check for cracks (Fig. 2) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection*.

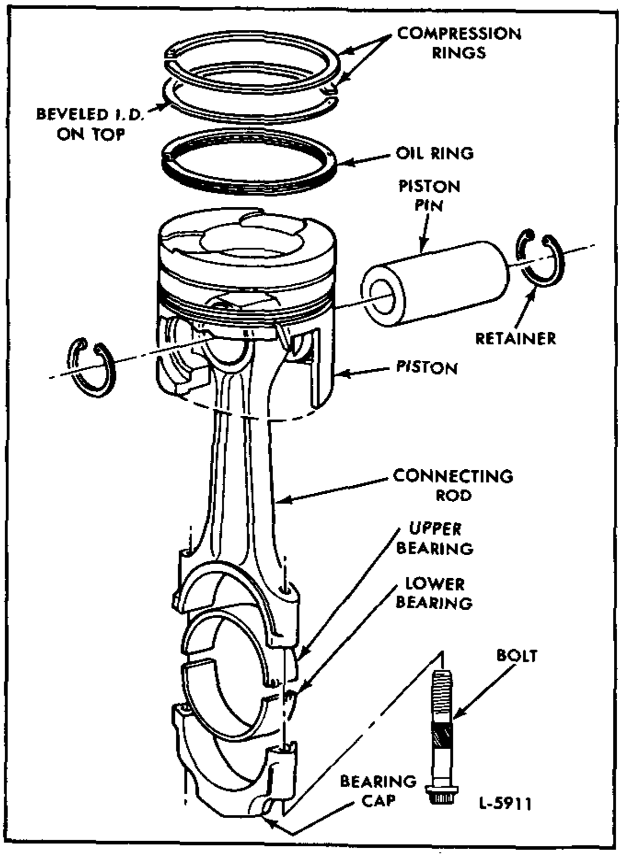


Fig. 1 - Connecting Rod and Piston Assembly

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap on the balance weight side.

> **NOTE:** Clean the rust preventive from a service replacement connecting rod. Be sure the oil hole at the top of the rod is not clogged. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Check the connecting rod bushing for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep, leading to early bearing failure.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod bushing and the piston with relatively small clearances. Replace piston and piston pin when clearance between them exceeds .07 mm (.0027"). Replace connecting rod and pin when clearance between them exceeds .098 mm (.0038").

Assemble Connecting Rod to Piston

Refer to Fig. 1 and assemble the connecting rod to the piston as follows:

1. Place the connecting rod with the small end up in a vise equipped with soft jaws.

2. Install one piston pin retainer in the retainer groove of the piston.

3. Apply clean engine oil to the piston pin.

> **NOTE:** Balance weight on connecting rod must be on the same side as the valve depressions in the piston crown.

Align the pin holes in the connecting rod and piston and insert the piston pin.

4. Install the second retainer in the piston groove. Rotate both retainers to be sure they are seated properly in the retainer groove.

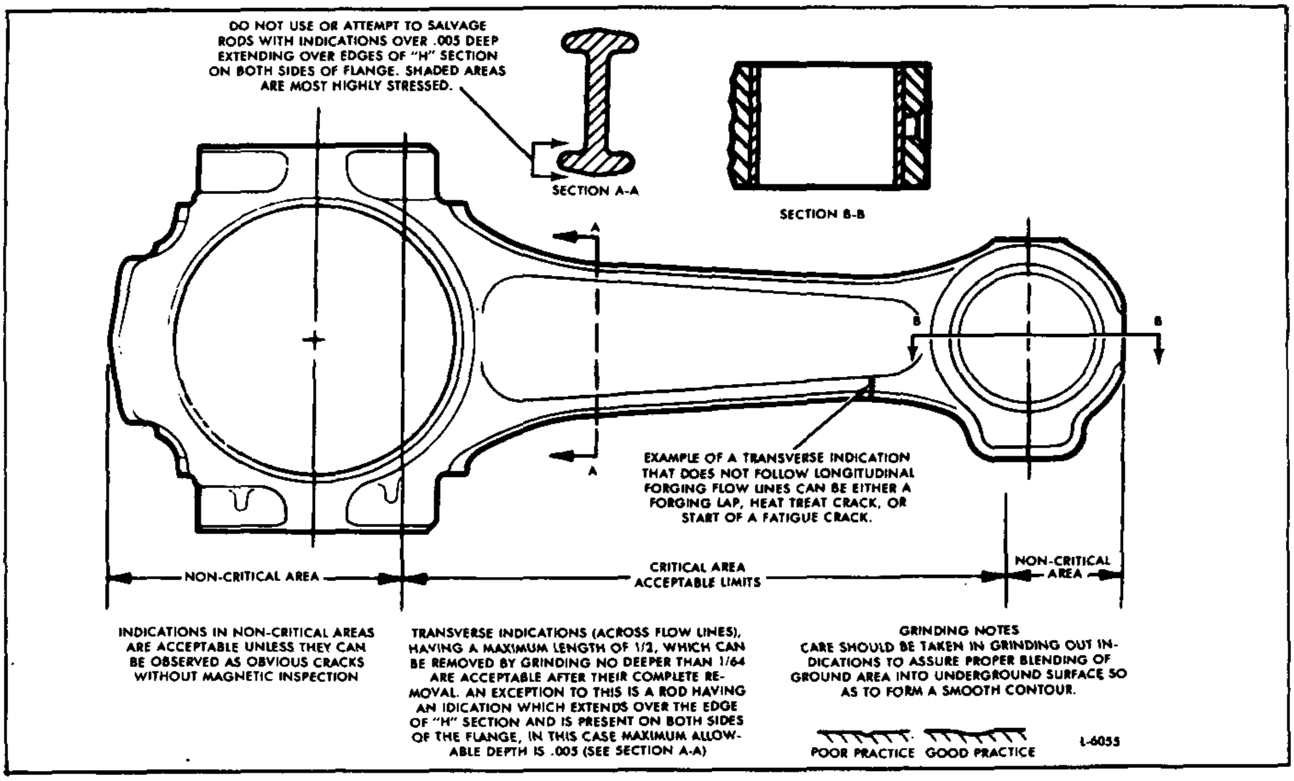


Fig. 2 - Magnetic Particle Inspection Limits for Connecting Rod

5. After the piston pin retainers have been installed, check for piston pin end clearance by cocking the connecting rod and shifting the pin in its bushing. The pin must also be free to rotate.

6. Install the piston rings on the piston as outlined in Section 1.6.

7. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

8. Install the upper bearing shell in the connecting rod. Lubricate the bearing shell with clean engine oil.

9. Position the piston and rod assembly in line with the block bore (with piston loading tool on piston). Install the piston assembly with the valve depressions on the outboard side of cylinder block.

10. Push or pull the piston into the cylinder bore until the upper bearing shell is firmly seated on the crankshaft journal.

11. Place the lower bearing shell with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

12. Install the bearing cap and the bearing shell on the

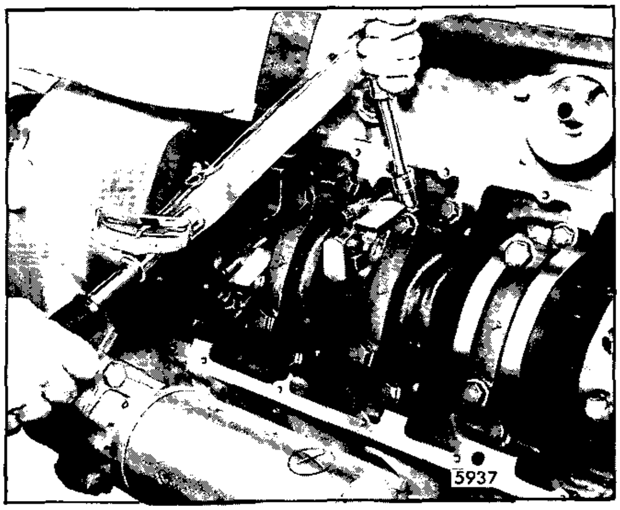


Fig. 3 - Torquing Connecting Rod Cap Bolts

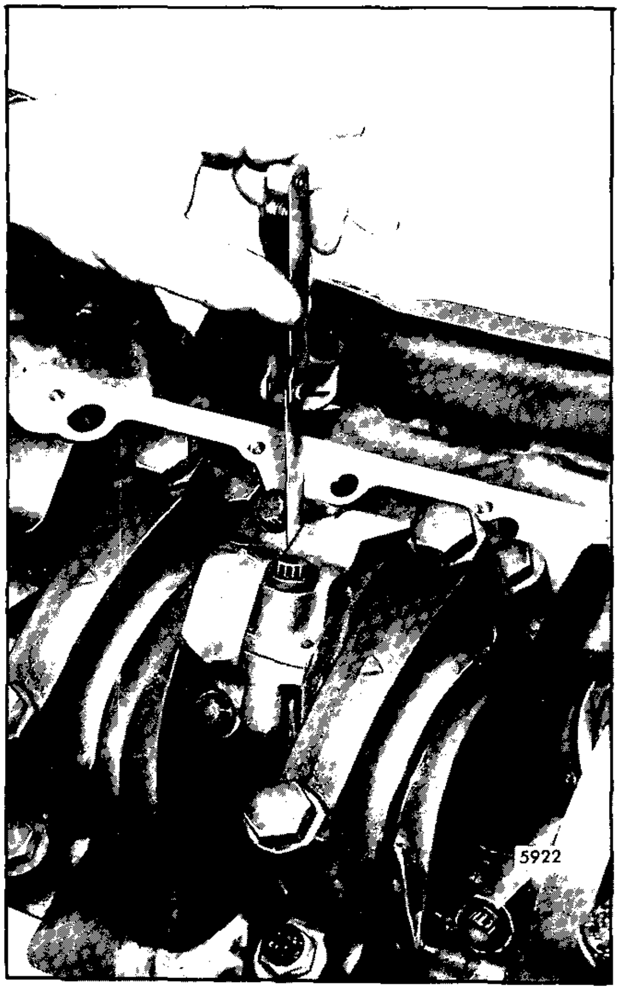


Fig. 4 - Measuring Connecting Rod Side Clearance

connecting rod with the identification numbers on the cap and the rod adjacent to each other.

13. Thread the connecting rod cap bolts in the rod. Tighten the bolts to 80-95 Nm (59-70 lb-ft) torque Fig. 3.

14. Measure the connecting rod side clearance Fig. 4. The clearance should be .20 - .52 mm (.008" to .020") between the connecting rods.

15. Install the remaining piston and rod assemblies in the same manner.

16. Install a new compression gasket as outlined in Section 1.2. Then install the cylinder head and any other parts which were removed from the engine.

17. After the engine has been completely reassembled, refer to the *Lubricating Oil Specifications* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

18. Install new water drain pipe plugs.

19. If the engine was removed, reinstall it into the chasis and fill the cooling system

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and replaceable.

They consist of an upper bearing shell seated in the connecting rod. The lower bearing shell is seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

Remove Bearing Shells

The connecting rod bearing caps are stamped 1, 2, 3 etc., with matching numbers stamped on the connecting rods. If they are not stamped turn the engine so the connecting rod journal is at the bottom. Stamp the cylinder numbers on the machined surfaces of the connecting rod and cap for indentification when reinstalling, then remove caps. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

NOTE: Stamp a new rod and cap on the same side before disassembly to be sure reassembly is in the same relationship.

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.

2. Remove the oil inlet pipe and screen assembly.

3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder bore far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.

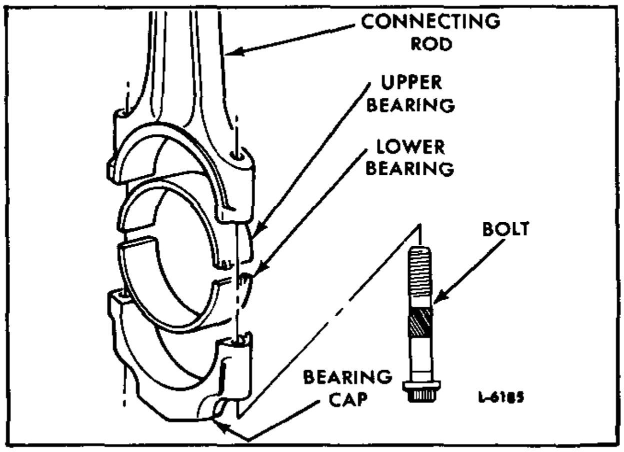


Fig. 1 - Connecting Rod and Bearing Shells

4. Inspect the upper and lower bearing shells as outlined under INSPECTION.

5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating. If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under INSPECTION in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than 2.370 mm (.0933") and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of 2.413-2.416 mm (.0950"-.0955).

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing. The maximum connecting rod bearing-to-journal clearance with used parts is .150 mm (.006").

Before installing the bearings, inspect the crankshaft journals (refer to INSPECTION in Section 1.3).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new crankshaft is to be used, install all new bearing shells.

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearing as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.

2. Install the upper bearing shell. Be sure the tang on the bearing shell fits in the groove in the connecting rod.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower shell in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.

5. Install the bearing and cap and tighten the bolts to 80-95 Nm (59-70 lb-ft) torque.

6. Install the lubricating oil pump inlet tube screen and bracket assembly.

7. Install the oil pan, using new gaskets.

8. Refer to the LUBRICATING OIL SPECIFICATIONS in Section 13.3 and fill the crankcase to the proper level on the dipstick.

GEAR TRAIN AND TIMING

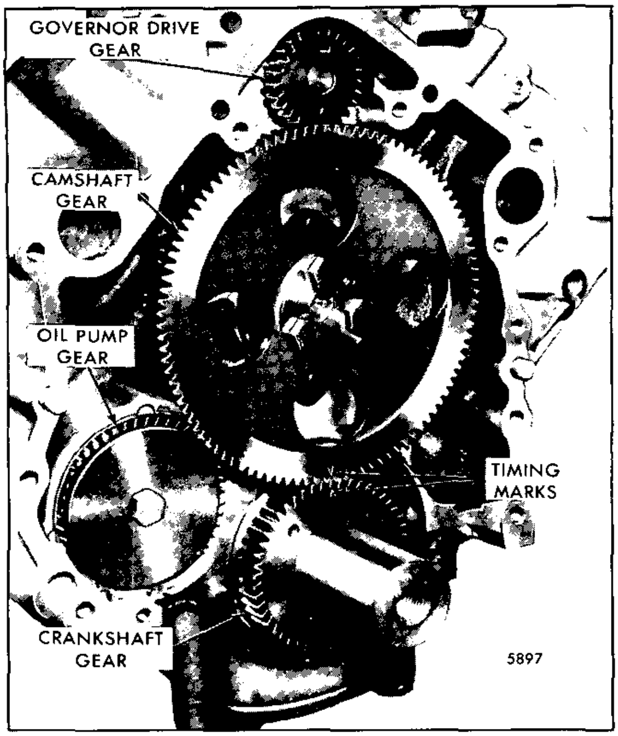


Fig. 1 - Engine Gear Train and Timing Marks Shown

A gear train located at the front of the engine is completely enclosed between the cylinder block and the front end plate.

The gear train consists of a crankshaft gear, camshaft gear, oil pump gear and governor gear.

The crankshaft gear is pressed and keyed on the front end of the crankshaft. The camshaft gear is attached to the front end of the camshaft with three bolts. The rotor type oil pump with integral gear fits into a recess in the front of the cylinder block. The crankshaft gear drives the camshaft gear. The camshaft gear drives the oil pump and governor drive gears.

Triangle timing marks are stamped on the face of the crankshaft and camshaft gears to facilitate correct gear timing. The gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 1). There are no timing marks on the oil pump or governor drive gears. Therefore, it is not necessary to align these gears in any particular position when meshing the crankshaft and camshaft gears.

> **NOTE:** Whenever a new cylinder block, crankshaft, camshaft or timing gear is installed, any previously determined injector timing heights are no longer valid. New base circle timing heights must be established by precision timing the engine (refer to Section 14.2.1).

Check the governor gear and oil pump gear backlash with the mating gear. The backlash should be 0.0762 - 0.152 mm (0.003-0.006") with new gears or 0.2286 mm (0.009") maximum with used gears. Check the crankshaft gear with the mating gear. The backlash should be 0.0762-0.1778 mm (0.003-0.007") with new gears or 0.2286 mm (0.009" maximum with used gears.

Lubrication

The gear train is lubricated by splash and the overflow of oil spilling into the gear train compartment.

CAMSHAFT AND CAMSHAFT BEARINGS

The camshaft is of the forged steel design with 24 lobes (Fig. 1). It is doweled at the front for mounting of the camshaft gear. Also, three tapped holes are provided for attaching the camshaft gear. A turbocharged engine has a different camshaft.

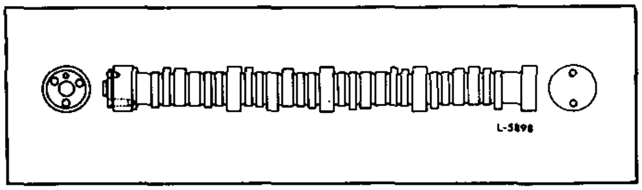


Fig. 1 - Engine Camshaft

Camshafts used in a naturally aspirated engine can be identified by an "N" being stamped or etched on the gear flange end of the camshaft. Camshafts used in turbocharged engines are identified by a "T".

The shaft is supported by bearings (bushing-type) that are pressed into bores in the cylinder block. Two end bearings (front and rear), two intermediate bearings and a center bearing are used to support the camshaft.

The five camshaft bearings are lubricated from passages intersecting the main bearing oil passage.

Remove Camshaft

Whenever an engine is being completely reconditioned or the bearings, thrust washer or the gear needs replacing, remove the shaft from the engine in the following manner:

1. Drain the engine cooling system.
2. Remove all accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.
3. Mount the engine on an overhaul stand. Be sure the engine is securely mounted on the stand before releasing the lifting sling.
4. Remove the air cleaner and adaptor.
5. Remove the turbocharger (if used) and connecting pipes.
6. Remove the air intake manifolds from both cylinder heads.
7. Disconnect the governor control linkage and fuel lines at the pump.
8. Remove the governor mounting bolts and lift the governor assembly off of the front cover.
9. Remove the bolts at the valley cover stiffeners, and lift the valley cover from the cylinder block.
10. Remove the rocker covers, rocker arms and push rods.
11. Remove the cam follower guide bolts and remove the guides and cam followers.
12. At the front of the engine remove the water pump, crankshaft pulley and engine mount.
13. Take out the remaining front cover bolts. With the oil pan bolts loose lift the cover from the dowel pins in the cylinder block. Discard the cover to block gasket. Clean off any gasket material from the end plate or cylinder block.
14. Remove three camshaft gear mounting bolts. Lift the gear off the dowel pin in the end of camshaft.
15. Remove the thrust washer attached to the block with two bolts.
16. Carefully withdraw the camshaft from the bore so as not to damage the cam bearings in the bore.

Inspect Camshaft

Wash the camshaft in clean fuel oil. Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers.

Refer to *Shop Notes* in Section 1.0 for measuring camshaft straightness.

Examine the bearing faces of the thrust washer. If the face is scored or if the thrust washer is worn excessively, replace the washer.

Also, examine the surfaces which the thrust washer contacts, if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts.

Inspect Camshaft Bearings

Inspect the camshaft bearings. If a bearing is scored, all camshaft bearings must be replaced.

Install the main bearing caps. Tighten the outer main bearing cap bolts to 90-103 N·m (66-76 lb-ft) and the inner main bearing cap bolts to 140-160 N·m (103-118 lb-ft).

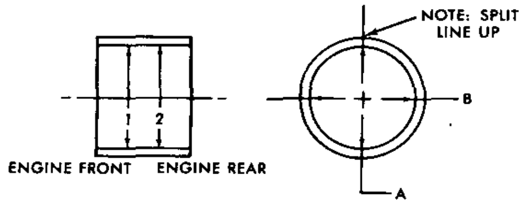
Measure and record (see Chart) the inside diameter of the camshaft bearings.

The inside diameter of a new camshaft bearing should be 65.19-65.22 mm (2.5665-2.5677"). The maximum worn limit is 65.32 mm (2.5717"). If the camshaft bearing inside diameter exceeds the maximum worn limit, all camshaft bearings must be replaced.

When the camshaft bearings have been measured and the dimensions noted, measure the camshaft journals. The journal diameters of a new camshaft should be 65.12-65.14 mm (2.5638-2.5646"). The maximum worn limit is 65.07 mm (2.5618").

Subtracting the camshaft journal dimensions from the camshaft bearing dimensions will give you the running clearance. The maximum running clearance permitted is 0.127 mm (0.005"). Should the running clearance exceed the specification, all camshaft bearings must be replaced.

The camshaft bearings are line bored in the cylinder block and are, therefore, in logitudinal alignment.



BEARING NO.	LOC.	POS. A	POS. B
FRONT	1		
NO. 1	2		
	1		
NO. 2	2		
	1		
NO. 3	2		
	1		
NO. 4	2		
REAR	1		
NO. 5	2		

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If a camshaft bearing is more than 0.05 mm (0.002") out of alignment, all camshaft bearings must be replaced.

If on inspection, it is noted that a bearing has spun in the bore and the cylinder block has blued, the block must be replaced. If blueing has not occurred, oversize outside diameter camshaft bearings can be installed.

Camshaft Bearing Removal

The procedure for restoring the inside diameter of the camshaft bearings to original specifications using a horizontal milling machine, is as follows:

1. Remove the damaged or worn camshaft bearings using J 29141-3 Driver and J 29141-1 Remover/Installer and a lead hammer (Fig. 2).

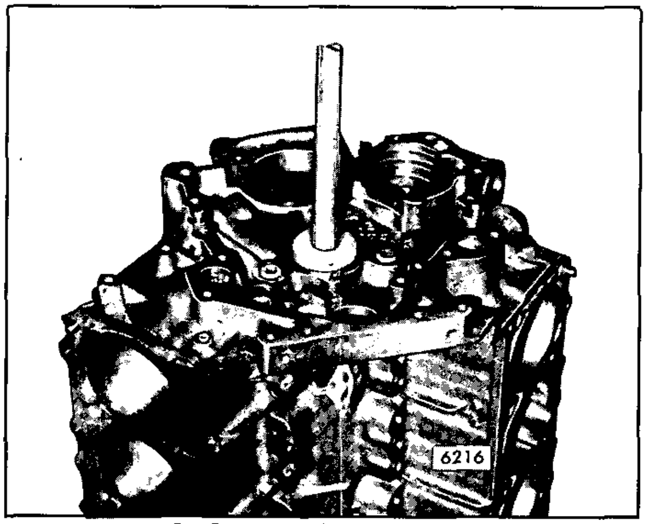


Fig 2 - Camshaft Bearing Removal

2. Using a dial bore indicator, measure the inside diameter of the cylinder block camshaft bore. It should be 69.12-69.15 mm (2.7213-2.7224"). If the readings taken are outside of these dimensions, oversize bearings must be installed.
3. If the bore is within specifications, install new camshaft bearings using J 29141-3 Driver, J 29141-1 Remover/Installer, J 29141-4 End Bearing Installer and J 29141-2 Pilot.

Camshaft Bearing Installation

The three center bearings (bearings 2, 3 and 4) and the front bearing (bearing 1) should be installed from the front of the cylinder block. The rear bearing (bearing 5) is installed from the rear of the block. The calibrated marks on Driver J 29141-3, when aligned with the top surface of Pilot J 29141-2, indicate the correct bearing location in the block (Fig. 3).

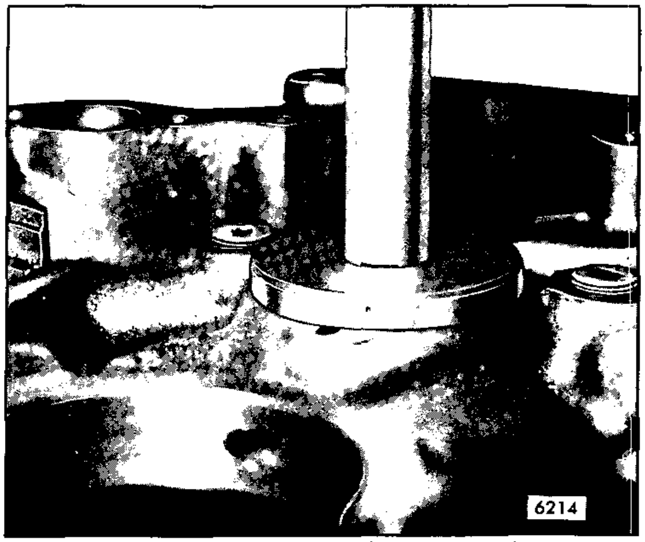


Fig. 3 - Installing Nos. 2, 3 and 4 Bearings

1. Place tool J 29141-3 Driver, J 29141-1 Remover/Installer and J 29141-2 Pilot into the camshaft bore, ensuring that the Pilot is properly seated in the front bearing location.
2. Place the new camshaft bearing into the No. 4 bearing location, ensuring that the bearing split line is at the top of the bore and the oil hole in the bearing is aligned with the oil supply hole in the camshaft bore.
3. Using a lead hammer, drive the bearing into the block until the calibrated mark on the Driver is flush with the top of the Pilot (Fig. 3).
4. Repeat the procedures in Steps 2 and 3 for bearings 2 and 3, using the relevant calibrated marks on the Driver.
5. Place a new camshaft bearing into the No. 1 location and follow the procedure in Step 2.
6. Using J 29141-3 Driver and J 29141-4 End Bearing Installer (Fig. 4), drive the No. 1

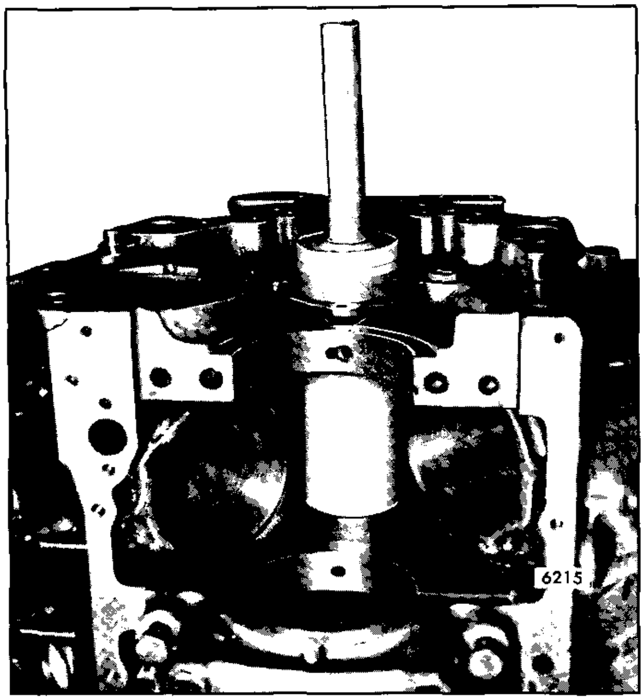


Fig. 4 - Installing End Bearing

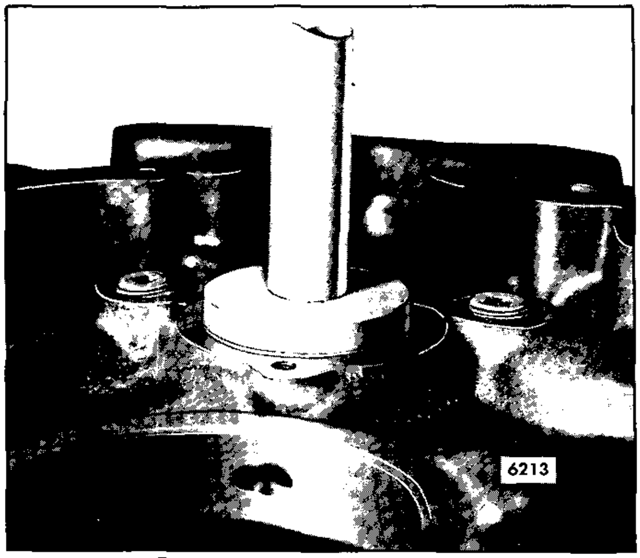


Fig. 5 - Installing End Bearing

bearing into the bore until the calibrated ring on J 29141-4 is flush with the front machined surface of the camshaft bore (Fig. 5).

7. Reverse the cylinder block, place a new camshaft bearing into the No. 5 bearing location and follow the procedures in Steps 2 and 6.

8. Tighten the outer main bearing cap bolts to 90-103 N·m (66-76 lb-ft) and the inner main bearing cap bolts to 140-160 N·m (103-118 lb-ft).

NOTICE: To prevent the possibility of camshaft bearing distortion, it is essential to torque the main bearing cap bolts to the correct specifications BEFORE machining the camshaft bearings.

Machining Camshaft Bearings

1. Secure the cylinder block to the mill table, oil pan rail down and the front of the block facing the spindle.
2. Square the block to the spindle using a 0.0025 mm (.0001") graduated dial indicator attached to the mill spindle. Check locations 1-2 and 2-3 (Fig. 6) they must be square to within 0.025 mm (.001"). Shim or realign the block as required to achieve this reading.
3. Using the same dial indicator, check the camshaft bore in front of the first bearing 4 (Fig. 6). A maximum T.I.R. of 0.0125 mm (.0005") is permitted. Adjust the block or the mill table as required to achieve this reading.
4. Move the spindle through the camshaft bores and repeat Step 3 at the rear of the last camshaft bearing 5. The T.I.R. at the front and rear locations must be the same.
5. The center of the camshaft bore has now been established.
6. Line bore the inside diameter of bearings to 65.19-65.22 mm (2.5665-2.5677") with a surface finish of 0.8 micrometers (32 microinches) maximum. Bore in-line within .05 mm (0.002") maximum T.I.R. Take a second cut on bearings to ensure proper dimensions and finish. Machine the bearings to the high side of the specifications to assure maximum clearance and to compensate for variance in gages. When line boring the inside diameter of the bearings, care should be taken on location. It is critical in relation to the backlash of the crankshaft, camshaft, governor and the oil pump gears.
7. Remove the cylinder block from the mill table.
8. Remove all drain plugs and oil plugs from the block and immerse the block in an agitated cleaning tank to remove all machining debris.
9. Using compressed air, dry the cylinder block. Direct air through all the oil passages to ensure that they are clean and dry.
10. Replace the drain plugs and oil plugs.
11. Lightly coat all machined surfaces of the block with oil to prevent rust.
12. Install lubriplate on the bearings for longer and better lubrication during run-in.

Oversize Camshaft Bearings

If on inspection, the cylinder block camshaft bore, refer to R, Fig. 7, is found to be greater than 69.15 mm (2.7224") due to wear or a bearing spinning, it will be necessary to machine all the camshaft bores to accept an oversize bearing. If blueing of the cylinder

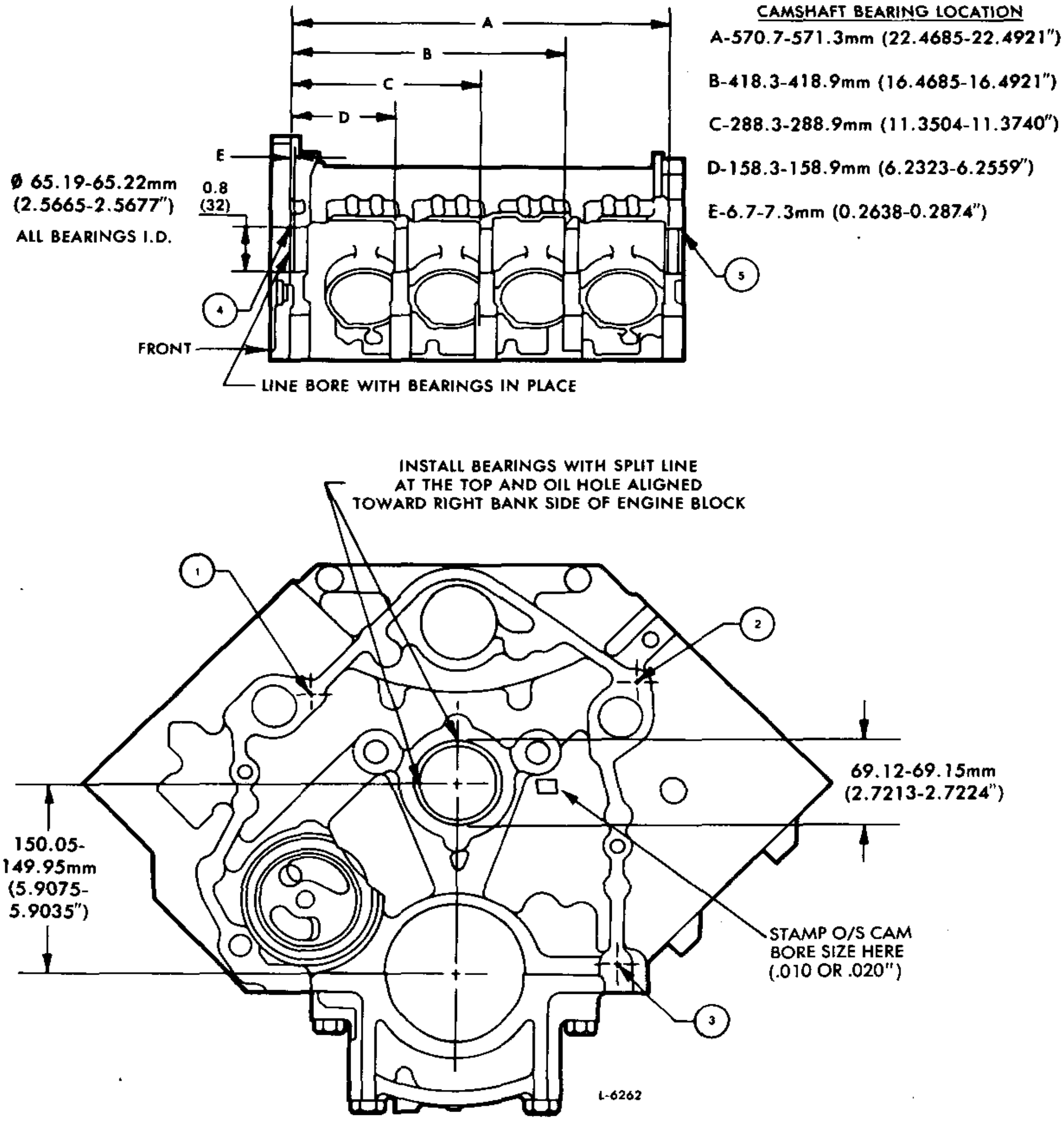


Fig. 6 - Camshaft Bearing Location

block has occured due to a bearing spinning, the cylinder block must be replaced.

The procedure for installing oversize camshaft bearings is as follows:

1. The procedures for machining the cylinder block camshaft bore to accept oversize camshaft bearings and for installing oversize bearings are the same as for standard size bearings. However, the cylinder block camshaft bore must be machined oversize.
2. Machine the camshaft bore to 69.37-69.40 mm (2.7311-2.7323") to accommodate the 0.254 mm (0.010") oversize bearing and to 69.63-69.66 mm (2.7413-2.7425") to accommodate the 0.508 mm (0.020") oversize bearing. The camshaft bore must be in-line within 0.05 mm (0.002") maximum T.I.R. and the surface finish 4.0 micrometers (160 microinches) maximum.
3. After the cylinder block camshaft bores have been bored oversize, use emery cloth to break the sharp edges of the bores (Fig. 7).
4. Install the camshaft bearings and finish the bore to the specifications provided in Step 6 for "Machining Camshaft Bearings".

Install Camshaft

1. Lubricate the bearings in the cylinder block with engine oil and slide the shaft into the cylinder block being careful not to damage the bearings or the cams and journals.
2. Place the thrust washer over the front end of the camshaft and attach it to the block with two bolts.

Tighten the bolts to 30-34 N·m (22-25 lb-ft) torque.

3. Install the camshaft gear over the dowel pin in the end of the shaft with the timing marks on the camshaft and crankshaft gear in alignment.
4. Secure the gear to the shaft with three bolts. Tighten the bolts to 58-66 N·m (43-49 lb-ft) torque.
5. Check the clearance between the thrust washer and the gear. The clearance should be .14 mm (.006") to .34 mm (.013").
6. Check the governor gear and oil pump gear backlash with the mating gear. The backlash should be 0.0762-0.152 mm (0.003-0.006") with new gears or 0.2286 mm (0.009") maximum with used gears. Check the crankshaft gear backlash with the mating gear. The backlash should be 0.0762-0.1778 mm (0.003-0.007") with new gears or 0.2286 mm (0.009") maximum with used gears. If the backlash is other than that specified, it will be necessary to try other timing gears until the correct backlash is obtained.
7. Install the front end cover using a new gasket.

NOTICE: Whenever a new cylinder block, crankshaft, camshaft or timing gear is installed, any previously determined injector timing heights are no longer valid. New base circle timing heights must be established by precision timing the engine.

8. Install or assemble the other parts or assemblies that were previously removed.

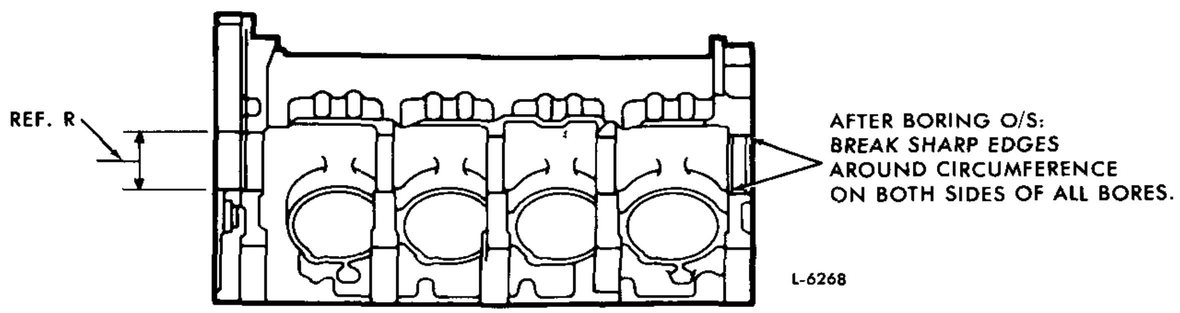


Fig. 7 - Camshaft Bore Inspection

CRANKSHAFT TIMING GEAR

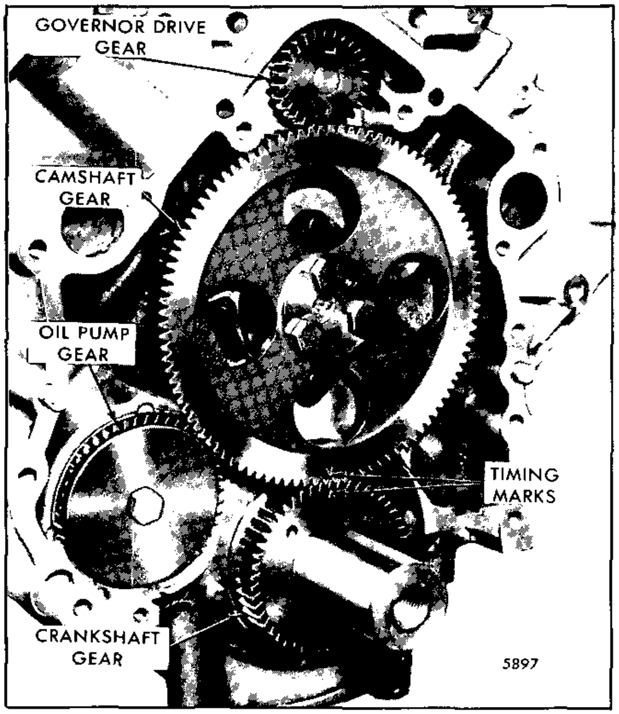


Fig. 1 - Crankshaft Timing Gear

The crankshaft gear is pressed and keyed on the front end of the crankshaft (Fig. 1). The crankshaft gear drives the camshaft gear. The camshaft gear drives the oil pump and governor drive gears.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the crankshaft gear and the camshaft gear (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Front Cover Removed)

Remove the gear as follows:

1. Before removing the crankshaft gear, align the timing marks of the gears and note their location so the gear can be reinstalled in its original position.

2. Using a suitable puller type tool, pull the gear off the end of the crankshaft.

Inspection

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severly damaged or worn, install a new gear. Also check the other gears in the gear train.

Install Crankshaft Timing Gear

1. If removed, install the Woodruff key in the keyway of the crankshaft.

2. Start the timing gear over the end of the crankshaft with the timing mark on the outer rim of the gear facing out and the keyway in the gear in alignment with the Woodruff key in the crankshaft.

3. Align the timing mark on the crankshaft gear with the timing mark on the camshaft gear (refer to Section 1.7.1).

4. Using a suitable tool press the gear up against the shoulder on the crankshaft.

5. Check the gear backlash with the mating gear. The backlash should be 0.0762 - 0.1778 mm (0.003 - 0.007") with new gears or 0.2286 mm (0.009") maximum with used gears.

> **NOTE:** Whenever a new cylinder block, crankshaft, camshaft or timing gear is installed any previously determined injector timing heights are no longer valid. New base circle timing heights must be established by precision timing the engine.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

MODIFICATION OF TOOL J 29008 FRONT CRANKSHAFT SEAL INSTALLER

The front oil seal installer tool J 29008 for the Fuel Pincher engine was designed originally to drive the front seal flush with the engine front cover.

An engineering study of the seal installation procedure concluded that the seal should be recessed 3.0 to 3.5 mm (.1179"-.1378") into the front cover and that it should be pulled into place rather than driven.

The tool manufacturer is modifying their stock of tool J 29008 to agree with these new installation specifications.

Distributor and dealer service organizations who have purchased the original design tool may rework it using the following instructions and Fig. 1.

1. Place tool J 29008 in a lathe having a four jaw chuck. The bell shaped end of the tool should be positioned 88.9 mm (3.5") from the chuck.

2. Use a dial indicator, to make sure that tool runout is .0508 mm (.002") or less.

3. Using a cut off type tool, machine a step into the outer skirt of the bell which is 3.0-3.5 mm (.1179-.1378") wide having a step diameter of 79.3-79.5 mm (3.125 ±.005") from the bell end.

4. Cut off the shank end of the tool 74-75 mm (2.950 ±.020") from the bell end.

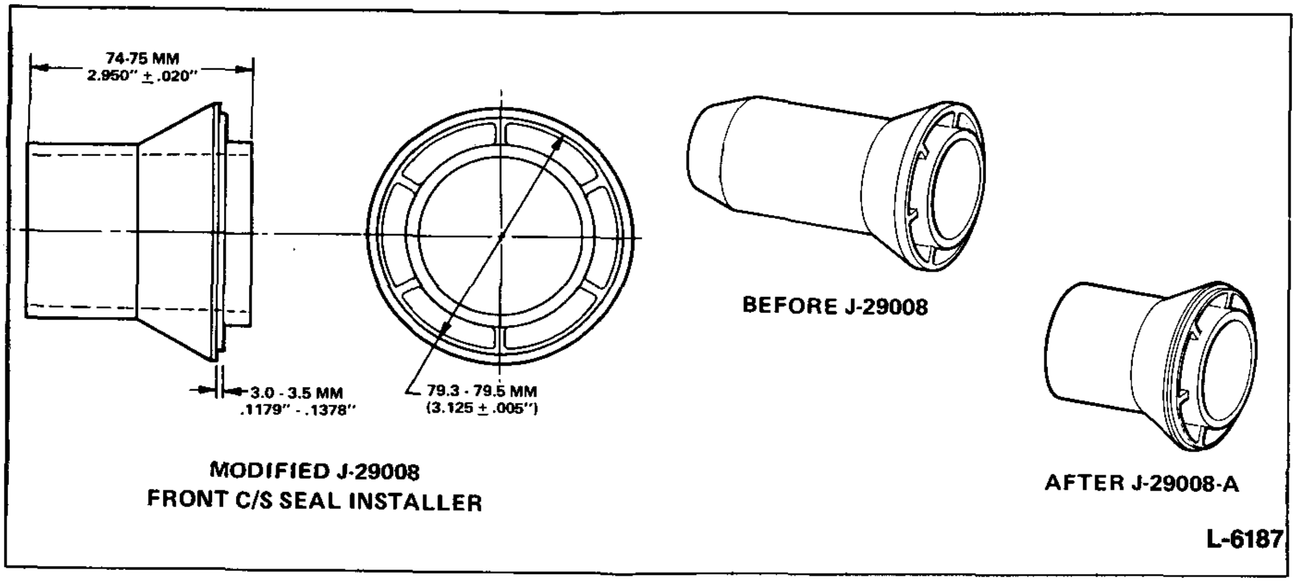


Fig. 1 - Modification of Tool J 29008

CHECKING CAMSHAFT STRAIGHTNESS

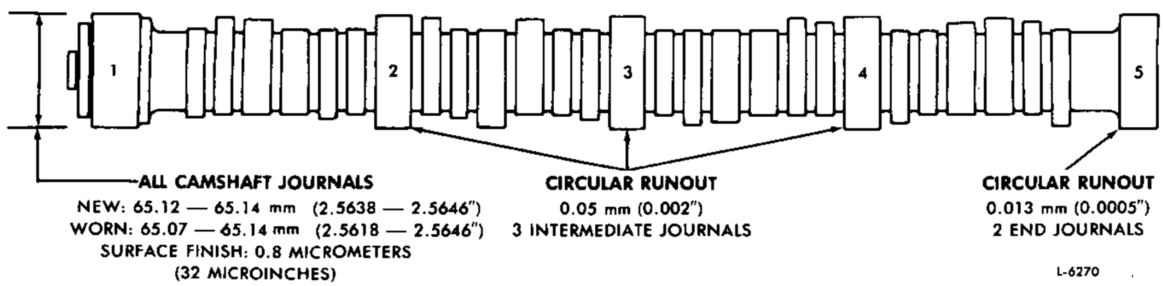


Fig. 2 · Checking Camshaft Straightness

To check the camshaft for straightness refer to Fig. 2 and proceed as follows:

1. Clean the camshaft in solvent and dry with compressed air.

2. Support the camshaft on V-blocks on a flat surface at No. 1 and No. 5 bearing journals.

3. Check the circular run out on Nos. 2, 3 and 4 bearing journals. It should not exceed 0.05 mm (0.002").

4. Check the circular run out on No. 1 and No. 5 bearing journals. It should not exceed 0.013 mm (0.0005").

If the circular runout exceeds the specified limits, replace the camshaft. No straightening operation is permitted.

REWORKING FLYWHEEL CLUTCH FACE

During normal operation, the clutch face surface of a SAE No. 2 flywheel, used with a manual transmission, can incur wear of damage. Rework of the flywheel and this surface is permissable if the minimum dimensions are maintained as indicated in Fig. 3.

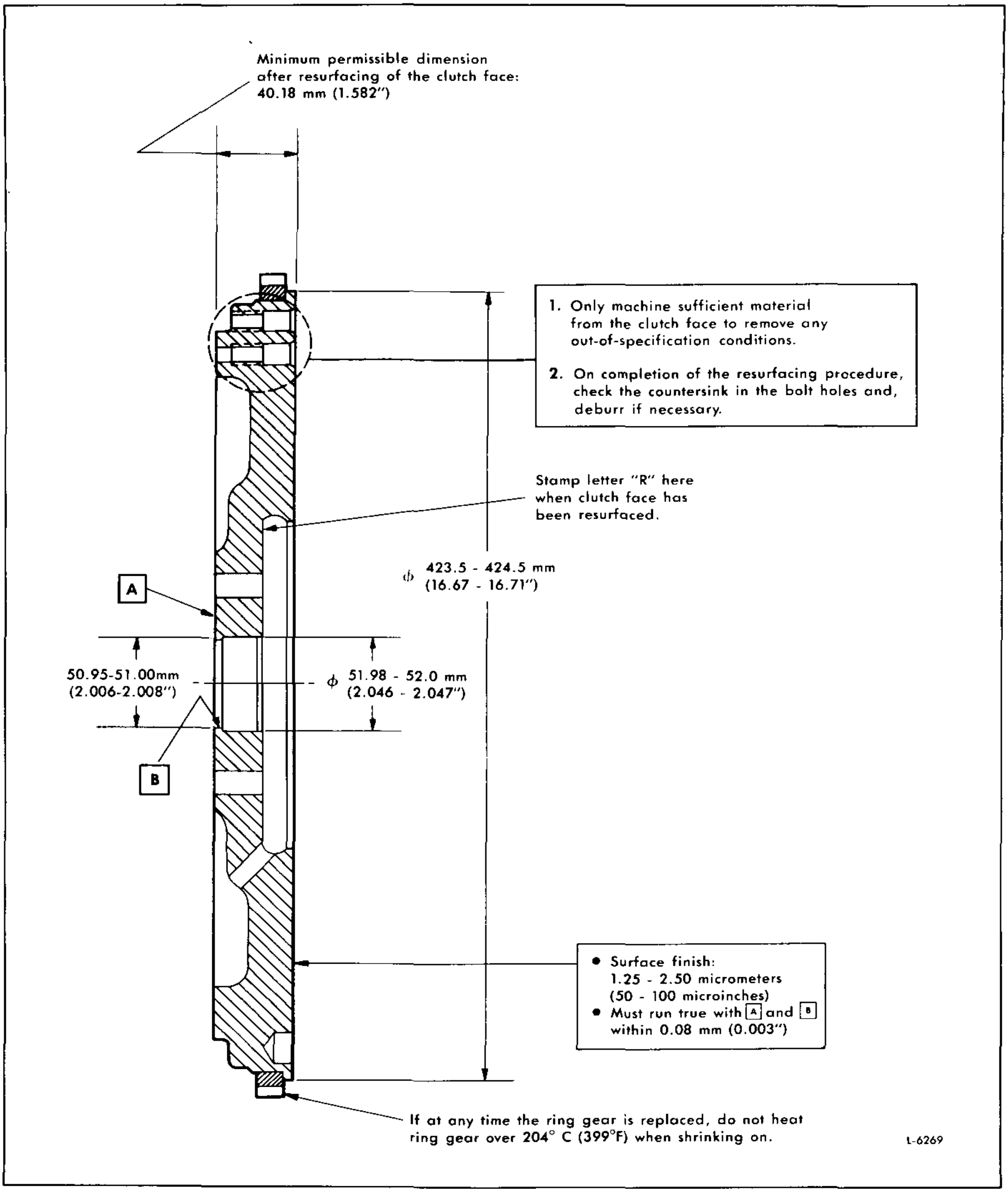


Fig. 3 - Flywheel Rework

Servicing 8.2L Cylinder Block Bores

When cylinder block bores experience damage or wear, they can be repaired by different methods which are explained below. It is imperative that the cylinder block be cleaned and checked for serviceability as outlined in Section 1.1, before any machining operations are performed. Thoroughly clean the fire decks of the cylinder block and check each for flatness and bolt hole boss protrusion as outlined in Section 1.1.

Preparation for Honing

1. The following steps should be taken to restore the cylinder bore to a serviceable condition:

A. Compare the cylinder bore measurements taken with the bore grade chart (Section 1.1). Select the next size bore that will, after rework is completed, remove all out-of-specification conditions.

B. Thoroughly inspect and prepare the honing equipment following the manufacturer's instructions.

Dry honing is an unsatisfactory method of honing. Wet honing is the only suitable method recommended. A good flow of clean flushing fluid or honing oil (kerosene, mineral spirits or a light-bodied mineral oil) should be directed into the cylinder bore before and during the honing process. The use of a flushing fluid or a honing oil will flush the abrasives and metal particles from the stones and cylinder wall. Equally important, it will cool the work and keep the stones clean and cutting freely. It also eliminates the possibility of the stones becoming loaded, which causes many of the small cutting edges to "push" rather than cut and produces a cylinder wall finish having deep scratches, smeared grooves, torn and fragmented material and glazed or burnished areas.

CYLINDER BORE SPECIFICATIONS	
Out of round	Maximum 0.025 mm (0.001")
Taper	Maximum 0.025 mm (0.001")
Surface finish	Range 0.5 - 0.8 micrometers (20-31 microinches) free of burnish, glaze, and embedded particles.
Recommended stone	80 or 220 grit
Crosshatch angle	Range 22° - 32° from horizontal. Cleanly cut, free of torn or folded metal and uniformly cut in both directions.
No boring tool marks are permitted.	

TABLE 1

2. When cylinder bores are honed, the following cylinder bore specifications must be met to ensure optimum piston ring seating, piston ring life and minimum oil consumption (See Table 1).

The surface finish is the average irregularity of the surface. This slightly irregular surface on the cylinder bore is required to allow new piston rings to seat correctly and to assist in correct oil retention.

The crosshatch angle (Fig. 4) is important for correct oil retention on the cylinder bore walls.

Failure to achieve the cylinder bore specifications could lead to slow piston ring seating, scratching and short ring life, high surface temperatures (scuffing), abnormal wear and excessive oil consumption.

3. Determine how the wear pattern should be removed by referring to the bore measurements taken during block inspection (Section 1.1).

4. Depending on the type of hone being used, place a stop below the cylinder being honed to prevent the stones from striking the main bearing journal.

5. Following the hone manufacturer's instructions, assemble the hone with 220 grit stones, place it into the bore and expand the stones and guides firmly against the cylinder wall. Do not overtighten. If using 80 grit stones, only hone to within .025 mm (.001") of required finish dimensions. Change to 220 grit to achieve the correct surface finish and final dimension. An overtight hone may cause severe damage to the stones. To ensure accurate honing, if the hone has two stones and two felt wiping pads, the two felt pads should be removed and replaced with two additional stones of the correct grit.

Felt pads, if used during the wet honing operation, deteriorate quickly, allowing the stones to move off center. The additional two stones, while honing, also act as guides. Caution must be exercised if a four stone hone is used as the amount of bore material being removed is almost double that of a two stone hone.

6. Start the bore flushing equipment and make any necessary adjustments to the rate of flow and direction of the flushing fluid. Failure to provide a plentiful supply of honing oil to the cylinder bore while honing can cause premature engine failure. One of the major purposes of the honing oil is to cool the cylinder walls while honing.

CAUTION: Personal injury could occur unless precautions are taken to ensure that no flushing

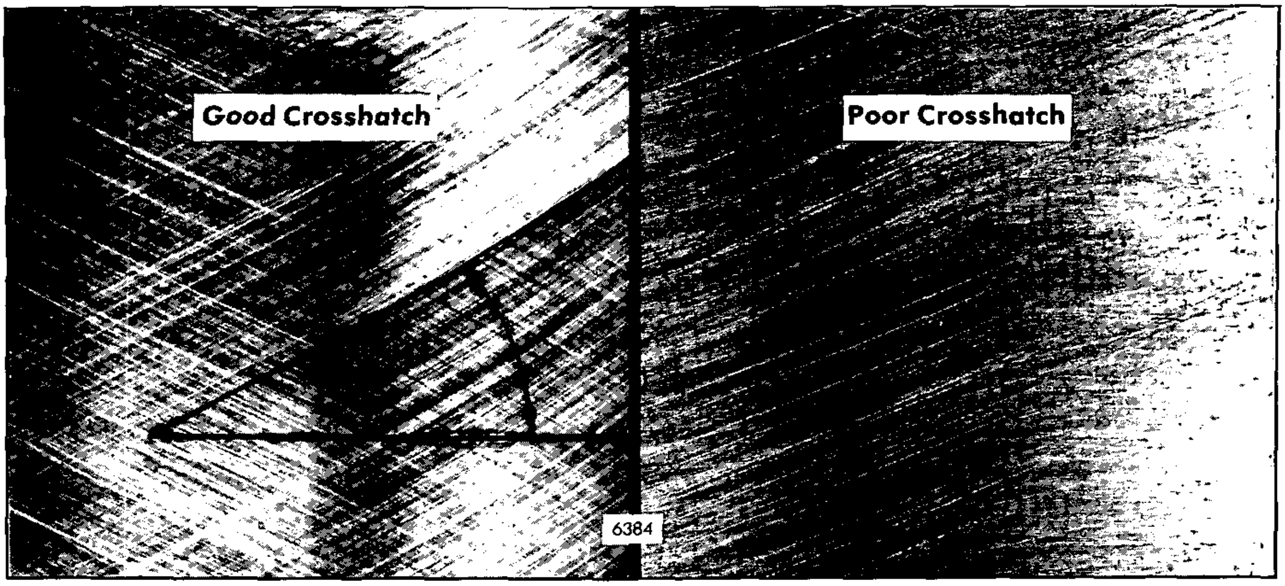


Fig. 4 - Cylinder Bore Crosshatch Pattern

fluid is permitted to come in contact with the electrical equipment or cables.

An inadequate supply of cooling fluid will allow the cylinder wall to heat up and expand. This will give a false reading when measurements are taken. When measuring any component of the 8.2L engine, it is necessary that the part being measured and the measuring equipment be as close to the same temperature as possible - e.g., a cylinder block with a temperature of 38° C (100° F) measured with a dial bore indicator of 21° C (70° F) will give a false reading of .018 mm (0.0007″). When the cylinder wall cools down, the inside diameter of the bore will be undersize. The need for correctly sized cylinder bores is easily recognized by referring to the 8.2L cylinder bore diameter chart in Section 1.1. You will see that there is only 0.016 mm (0.0006″) between grade sizes.

Using an oil can to provide a supply of honing fluid is not satisfactory and can cause the cylinder bore to expand in excess of one bore grade size. A pump for honing fluid can easily be manufactured by mounting an 8.2L (or other 2 cycle) fuel pump to a fractional horsepower electric motor.

The Honing Method

Remove Taper as Follows:

1. Start the hone motor, ensuring that the motor and hone are centered on the bore. Start stroking at the bottom or least worn section of the cylinder, using short strokes in order to concentrate the honing in this area.

2. Gradually lengthen strokes as metal is removed and stones contact higher on the bore.

3. Occasionally stroke all the way to the top of the bore to remove any ring ridge that may be present (approximately four short strokes, then two full strokes (Fig. 5).

4. Expand stones as necessary to compensate for stock removal, keeping the stones firmly against the cylinder walls. Do not permit the stones to extend more than 12.7 mm (0.500″) below or more than 25.4 mm (1.00″) above the cylinder bore.

5. Depending on the amount of stock to be removed, stop the hone motor after approximately 15-20 seconds of honing, but continue stroking until the hone stops revolving.

6. Loosen the adjustment on the hone and remove it from the bore.

7. Clean the cylinder bore and, using a bore gage, measure the amount of material removed.

8. Repeat Steps 1 thru 7 until the bore dimension required is reached. The crosshatch angle is a function of the speed of the hone motor and the stroking speed of the hone; i.e., using a 400 rpm half inch drill motor, the stroking speed is approximately 45-50 strokes per

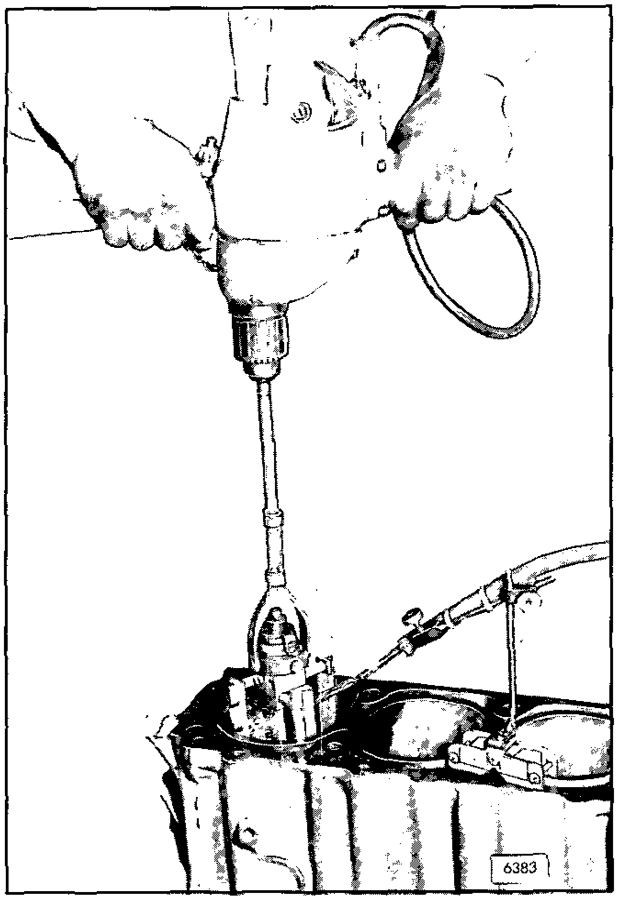


Fig. 5 - Honing Cylinder Block Bore

minute to obtain a crosshatch angle of 22-32° . A slight increase in motor speed and reduction of torque felt at the drill handle is an indicator of the stones' cutting action.

9. When the selected dimension is reached, it will be necessary to regrade the bore by "X"ing out the original grade on the block and stamping the new grade alongside the cylinder that has been reworked (Fig. 6). The left cylinder is a grade B bore - .127 mm (0.005") oversize. The right cylinder has been reworked and regraded to a C bore. Refer also to "Grading The Cylinder Bores" in Section 1.1. The figure stamps used should not be greater than 6.350 mm (0.25").

Cleaning

1. Thorough cleaning of the cylinder block is essential after the honing operations are completed. Failure to properly clean all honing debris from the block could

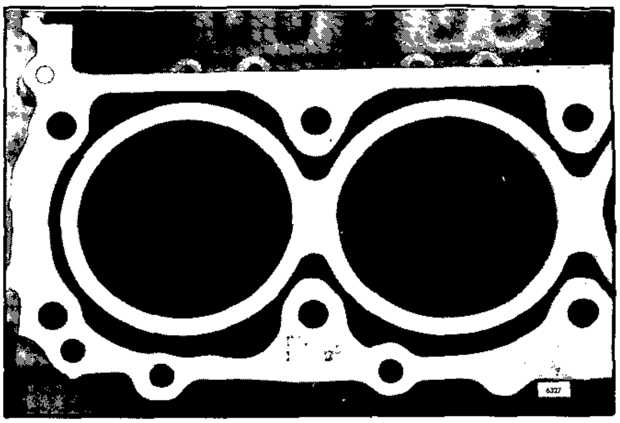


Fig. 6 - Reworked Cylinder Bores

result in short cylinder component life and bearing damage throughout the engine.

2. Using hot soapy water, scrub the cylinder bores with a stiff, non-metallic bristle brush to remove any honing debris. continue cleaning the bore until the replenished soapsuds remain white. Do not use diesel fuel, kerosene of commercial solvents to clean the cylinder bores after honing. Solvents of this nature do not remove abrasives from the cylinder walls.

3. Wipe out the bores with clean white paper towels. If, after continued wiping, a gray or black residue is seen on the towels, it will be necessary to rewash the bore.

4. When the bores are properly clean, dry the block using compressed air.

5. Coat all the cylinder bores and machined surfaces on the block with a suitable lubricating oil to prevent rust.

The Boring and Honing Method

Boring is necessary as an initial step for sizing a bore to oversize pistons. Honing is necessary to establish the piston-to-bore clearances for the different grade (A, B or C) pistons. Proceed as follows, if during the block inspection (Section 1.1), it is determined that boring is necessary to return the cylinder bore to a serviceable condition. It is not necessary to bore all the cylinder bores unless they are all out of specification. The standard and oversize pistons are the same weight. Any combination of pistons can be mixed in an engine.

1. Torque the main bearing cap inboard bolts to 140-160 Nm (103-118 lb-ft) and the outboard bolts to 90-103 Nm (66-76 lb-ft).

2. Assemble the boring equipment following the manufacturer's instructions and recommendations.

3. Following the manufacturer's instructions and *standard trade practices, machine the cylinder bore* to 0.025-0.038 mm (0.001-0.0015") less than the required finish dimension to allow for honing.

4. Chamfer the top of the cylinder bore (Fig. 7).

5. When boring is completed, carry out the honing operation. Refer to "Preparation for Honing".

6. *Stamp the block with the oversize dimension* e.g., (.127 mm or .005") adjacent to the cylinder bore that was reworked (Fig. 6).

The Boring and Sleeving Method

If a cylinder bore is damaged so that an oversized piston cannot be used, the cylinder bore can be bored to accept a sleeve kit which will put that cylinder back to *standard size. Boring and sleeving operation is covered* in the following procedure.

1. Clean all preservative from the sleeves, using a suitable solvent.

2. Cut the sleeves to the length shown in Fig. 8. Cut stock from the end marked by yellow paint. Do not cut from the end with 10° lead in chamfer.

3. Measure and record the O.D. of each sleeve.

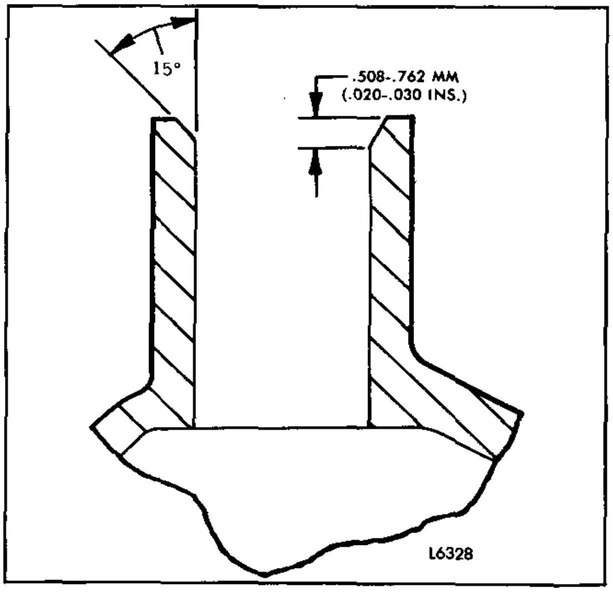


Fig. 7 - Chamfer Top of Cylinder Bore

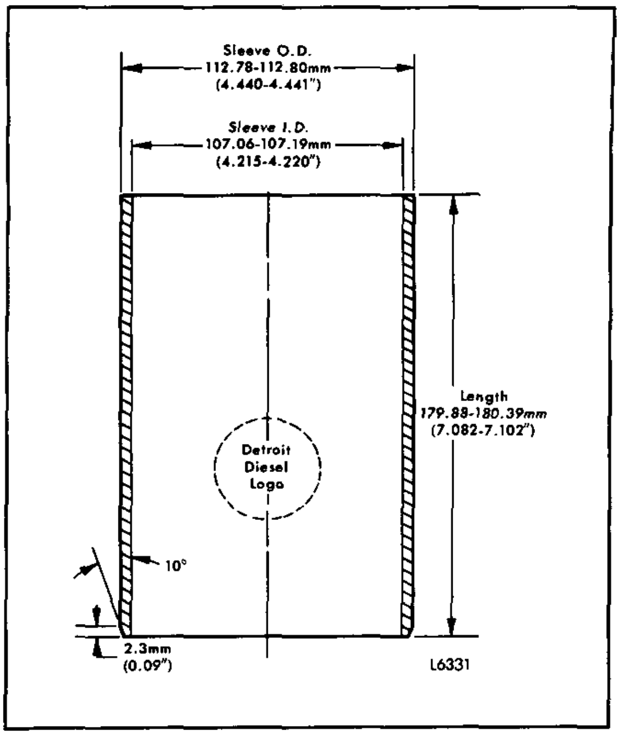


Fig. 8 - Dimensions After Cut

4. Torque main bearing cap inboard bolts to 140-160 Nm (103-118 lb-ft) and the outboard bolts to 90-103 Nm (66-76 lb-ft).

5. Thoroughly clean the fire decks of the cylinder block and check each for flatness and bolt hole boss protrusion as outlined in Section 1.1.

6. Thoroughly clean the cylinder bores of the cylinder block.

7. Center the boring bar at the bottom end of the cylinder bore. This will permit correct alignment of the sleeve.

8. Refer to the sleeve O.D. dimensions recorded in Step 3, and bore cylinder bores to diameters that establish a 0.038-0.051 mm (0.0015-0.002") press fit between sleeves and cylinder bores (Fig. 9). Follow the manufacturer's instructions on correct boring machine usage.

9. Install the sleeves with a press or a suitable puller. Under no circumstances should hte sleeve be pounded into the cylinder bores. Striking the top of the sleeve with a hammer or other object may cause cylinder bore distortion or structural damage to the cylinder block or sleeve. When installed, the sleeves should protrude 1.08-2.08 mm (0.043-0.082") above the cylinder bore.

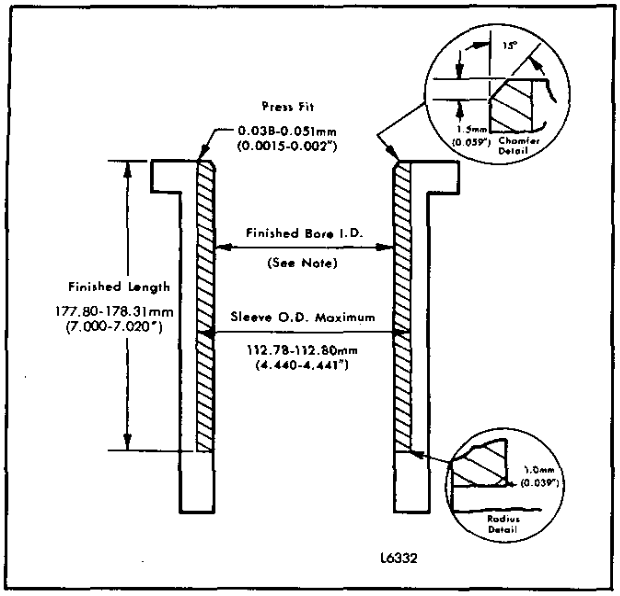


Fig. 9 - Dimensions After Installation

10. Remove excess sleeve stock so that the top of the sleeve is flush with the top of the cylinder bore. Do not remove sleeve stock below the top of the cylinder bore. This will result in the head gasket not sealing.

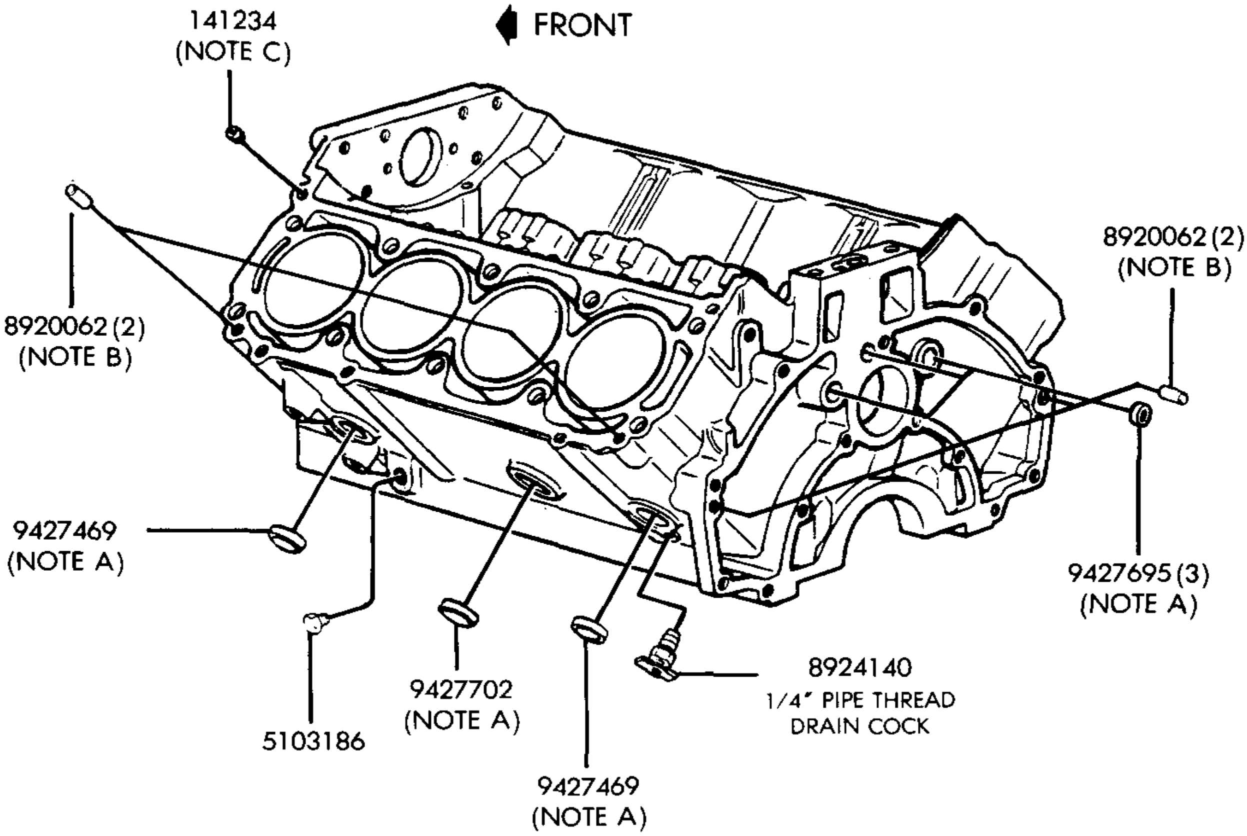
11. Using a suitable cutting tool in the boring bar, machine a 15° chamfer on the top of the sleeve to facilitate piston ring installitation (Fig. 9).

12. Finish bore and hone the sleeved cylinder bores. Refer to the "Boring and Honing Method" to achieve the inside diameter specified for the replacement pistons.

Bore diameters for standard grades A, B and C and oversize grade B pistons are provided in the Chart in Section 1.1.

When a cylinder bore has been sleeved, it is recommended that the inside diameter of the sleeve be bored and honed to standard dimension.

CYLINDER BLOCK PLUGGING CHART



Pipe Plug Identification Chart		
5103186	– 1/2"	Hex Hd.
Standard Pipe Plug Torque Chart		
Pipe Plug Size	Torque Nm – (lb. ft.)	
1/2"	31-36-(23-27)	
Cup Plug Identification Chart		
9427695 – 3/4"		
9427469 – 1 1/2"		
9427702 – 1 5/8"		
Dowel Pin Identification Chart		
141234 – 3/8"		
8920062 – 12 x 29 mm		

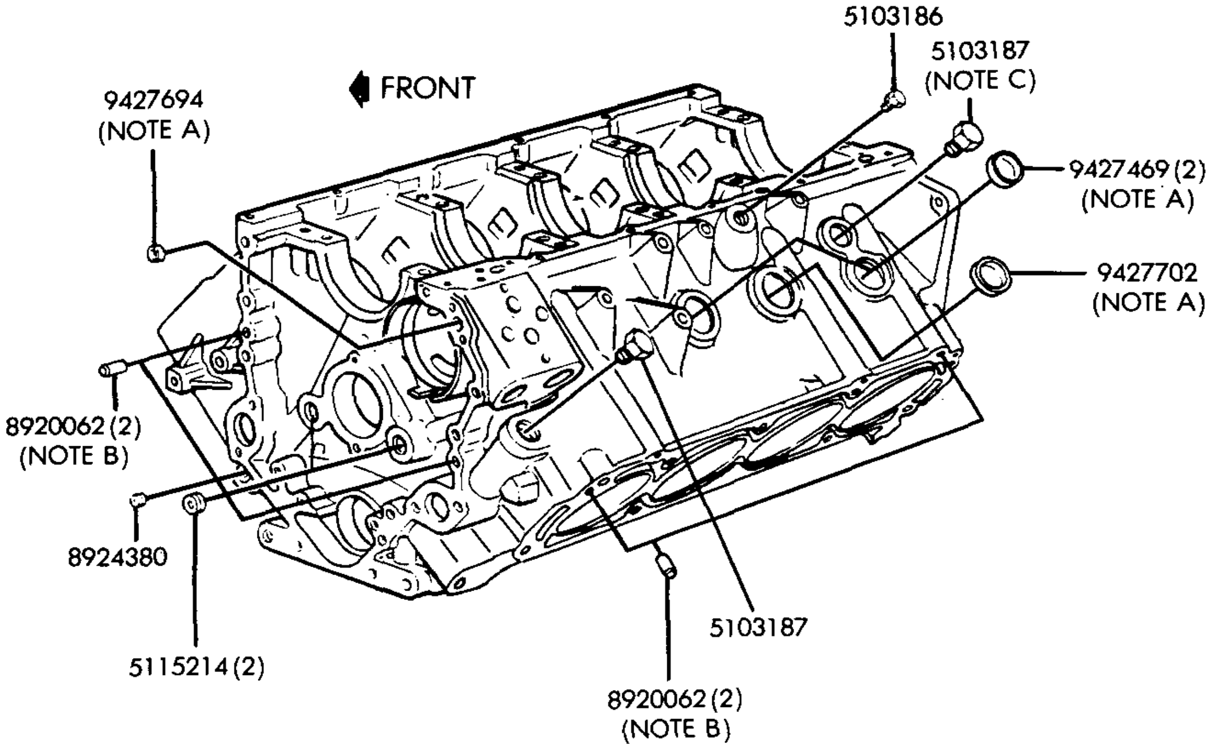
NOTES:

A. Must be 2.5 - 3.0mm (.098 - .118") below the surface. Cup plugs should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent.

B. 8920062 dowel pins — drive to 9.5 - 10mm (.374 - .394") projection.

C. 141234 dowel pin — drive until flush or to .3mm (.012") below the surface. Dowel pin should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent.

CYLINDER BLOCK PLUGGING CHART



Pipe Plug Identification Chart			
8924380	–	1/8″	Sq. Soc. Hd.
5103186	–	1/2″	Hex Hd.
5115214	–	1/2″	Sq. Soc. Hd.
5103187	–	3/4″	Hex Hd.

Standard Pipe Plug Torque Chart

Pipe Plug Size	Torque Nm – (lb. ft.)
1/8″	13-17-(10-12)
1/2″	31-36-(23-27)
3/4″	44-47-(33-37)

Cup Plug Identification Chart

9427694 – 11/16″
9427469 – 1 1/2″
9427702 – 1 5/8″

Dowel Pin Identification Chart

8920062 – 12 x 29 mm

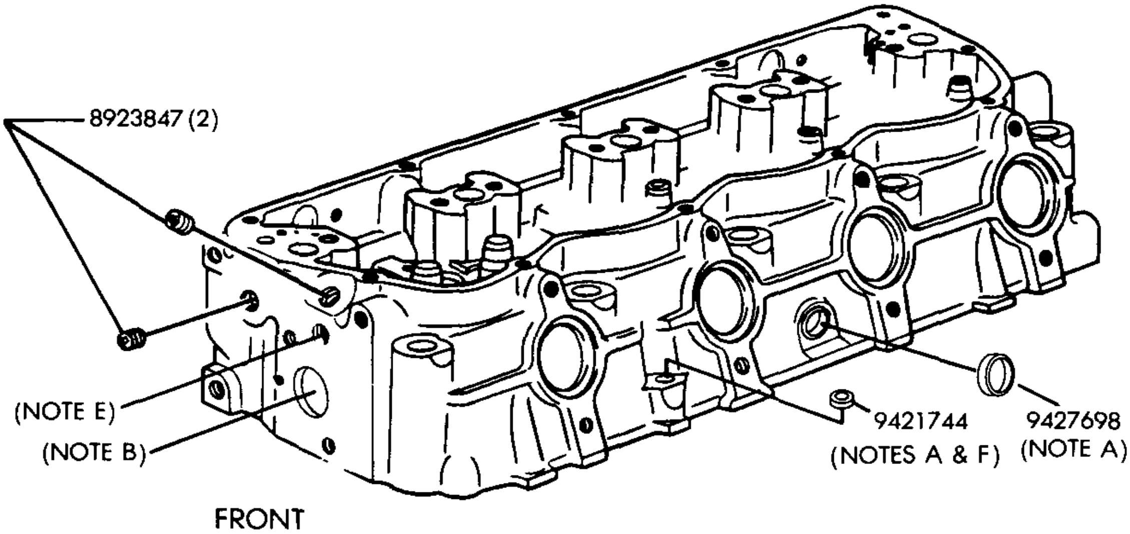
NOTES:

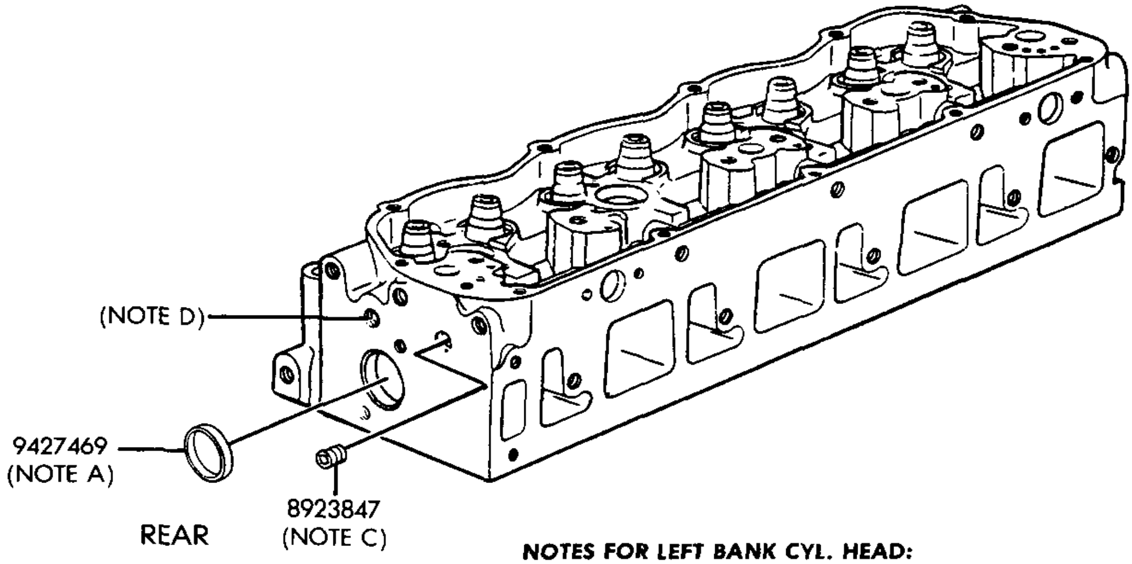
A. Must be 2.5 - 3.0mm (.098 - .118″) below the surface. Cup plugs should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent.

B. 8920062 dowel pins — drive to 9.5 - 10mm (.374 - .394″) projection.

C. Marine application does *not* require pipe plug (5103187) in this location.

LEFT BANK CYLINDER HEAD PLUGGING CHART





Pipe Plug Identification Chart	
8923847 – 1/4″ Sq. Soc. Hd.	
Standard Pipe Plug Torque Chart	
Pipe Plug Size	Torque Nm – (lb. ft.)
1/4″ —	19-22-(14-16)
Cup Plug Identification Chart	
9421744 – 7/16″	
9427698 – 1″	
9427469 – 1 1/2″	

NOTES FOR LEFT BANK CYL. HEAD:

A. Must be 2.5 - 3.0mm (.098 - .118″) below the surface. Cup plugs should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent.

B. Does *not* require cup plug (9427469) in this location.

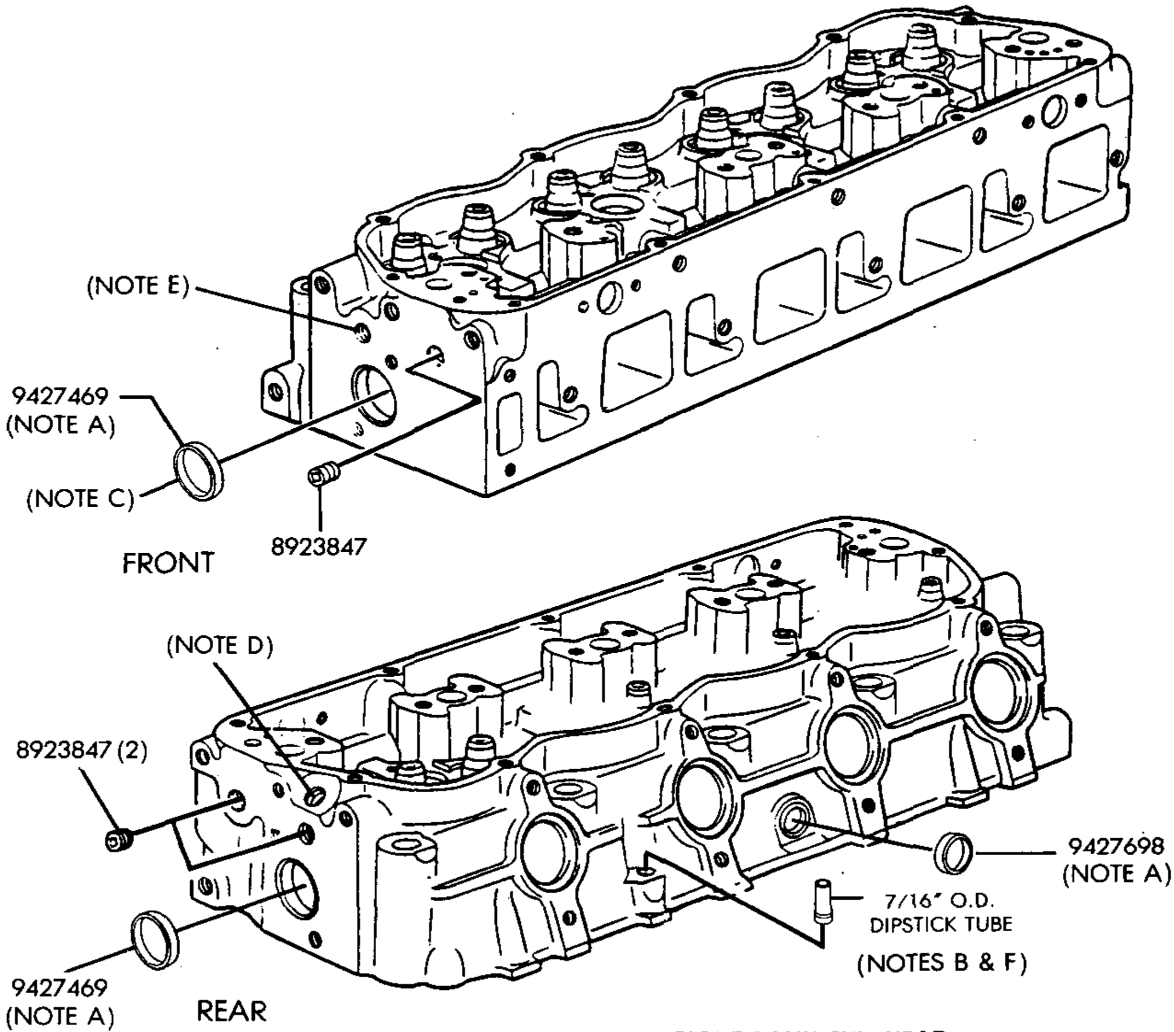
C. Does *not* require pipe plug (8923847) in this location if used for oil pressure gage hookup or if used for marine application.

D. 1/4″ pipe thread fuel fitting (return line).

E. 1/4″ pipe thread fuel fitting (inlet line).

F. With marine applications the location of the dipstick tube will vary in order to provide accessibility. Therefore, the dipstick tube may be installed on either the left or right bank cylinder head. The cup plug (9421744) *must* be installed on the opossite bank. See notes A and B of "Right Bank Cyl. Head" for installation of cup plug and dipstick tube respectively.

RIGHT BANK CYLINDER HEAD PLUGGING CHART



Pipe Plug Identification Chart	
8923847 – 1/4" Sq. Soc. Hd.	
Standard Pipe Plug Torque Chart	
Pipe Plug Size	Torque Nm – (lb. ft.)
1/4" —	19-22-(14-16)
Cup Plug Identification Chart	
9427698 – 1"	
9427469 – 1 1/2"	

NOTES FOR RIGHT BANK CYL. HEAD:

A. Must be 2.5 - 3.0mm (.098 - .118") below the surface. Cup plugs should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent.

B. Tube should be cleaned prior to application of sealant. Apply a good grade of non-hardening sealant such as "Gasoila" varnish type sealer or an equivalent around the bottom O.D. of the tube. Drive in till bottomed.

C. Marine application does *not* require cup plug (9427469) in this location.

D. 1/4" pipe thread fuel fitting (return line).

E. 1/4" pipe thread fuel fitting (inlet line).

F. With marine applications the location of the dipstick tube will vary in order to provide accessibility. Therefore, the dipstick tube may be installed on either the left or right bank cylinder head. The cup plug (9421744) *must* be installed on the opposite bank. See notes A and B of "Right Bank Cyl. Head" for installation of cup plug and dipstick tube respectively.

SPECIFICATIONS

TABLE OF SPECIFICATIONS

These specifications also apply to oversize and undersize parts.

ENGINE PARTS Naturally Aspirated and Turbocharged	MINIMUM	MAXIMUM
Cylinder Block		
Block Bore:		
Standard Bore:		
Grade A Piston	108.000 mm (4.2520″)	108.016 mm (4.2525″)
Grade B Piston	108.017 mm (4.2526″)	108.033 mm (4.2532″)
Grade C Piston	108.034 mm (4.2533″)	108.050 mm (4.2539″)
Oversize Bore (.127 mm - .005″):		
Grade B Piston	108.144 mm (4.2576″)	108.160 mm (4.2582″)
Oversize Bore (.254 mm - .010″):		
Grade B Piston	108.271 mm (4.2626″)	108.287 mm (4.2632″)
Oversize Bore (.508 mm - .020″):		
Grade B Piston	108.525 mm (4.2726″)	108.541 mm (4.2732″)
Out-of-round		.025 mm (.001″)
Taper		.025 mm (.001″)
Camshaft Bore:		
Standard Bore	69.12 mm (2.7213″)	69.15 mm (2.7224″)
Oversize Bore (.254 mm - .010″)	69.37 mm (2.7311″)	69.40 mm (2.7323″)
Surface Finish		4.0 micrometers (160.0 microinches)
Camshaft Bushing Bore:		
Standard Bore	65.19 mm (2.5665″)	65.22 mm (2.5677″)
Surface Finish		0.8 micrometers (32.0 microinches)
Oil Pump Bore:		
Standard Bore	79.400 mm (3.1260″)	79.438 mm (3.1275″)
Oversize Bore (.254 mm - .010″)	79.654 mm (3.1360″)	79.692 mm (3.1375″)
Oversize Bore (.508 mm - .020″)	79.908 mm (3.1460″)	79.946 mm (3.1475″)
Surface Finish		4.0 micrometers (160.0 microinches)

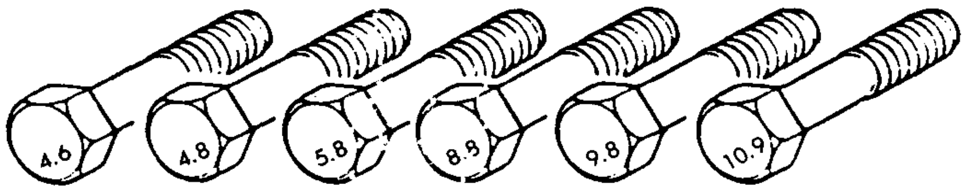
ENGINE PARTS Naturally Aspirated and Turbocharged	MINIMUM	MAXIMUM
Rework Locating Criteria for Centering:		
Between vertical C/L of bushing and vertical C/L of oil pump inner G-rotor hub.	3.77 mm (.1484")	3.85 mm (.1516")
This radius is from the center of the camshaft bore to the center of the oil pump bushing.	144.949 mm (5.7067")	145.051 mm (5.7107")
Oil Pump Bushing Bore:		
Standard Bore	76.20 mm (3.0000")	76.23 mm (3.0012")
Surface Finish		0.8 micrometers (32.0 micrometers)
Crankshaft*		
Standard Crankshaft:		
Main Journal	99.975 mm (3.9360")	100.000 mm (3.9370")
Crank Pin	69.975 mm (2.7549")	70.000 mm (2.7559")
Undersize Crankshaft (.254 mm - .010"):		
Main Journal	99.721 mm (3.9260")	99.746 mm (3.9270")
Crank Pin	69.720 mm (2.7449")	69.746 mm (2.7459")
Surface Finish		0.32 micrometers (13.0 micrinches)
Cylinder Head		
Firedeck Flatness:		
Transversly		0.10 mm (.004")
Longitudinally		0.15 mm (.006")
Value Seat Angles:		
Exhaust - Face		45°
Exhaust - Seat		46°
Intake - Face		30°
Intake - Seat		31°
Injector Tip Protrusion	3.04 mm (.120")	3.79 mm (.149")
Oil Pump		
Drive Gear Backlash	.076 mm (.003")	.152 mm (.006")

*1. No rework in the fillet areas is permitted. If any damage is discovered in these areas, prior to or after machining, the crankshaft must be discarded.
2. No straightening operations are permitted.
3. The crankshaft and grinding wheel must be rotated in a clockwise direction (as viewed from front of crankshaft).

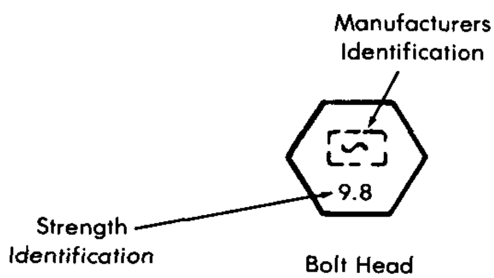
STANDARD METRIC BOLT AND NUT TORQUE SPECIFICATIONS

Thread Size Diameter × MM Per Thread	BOLT CLASSES / TORQUES		
	8.8	**9.8**	**10.9**
	Nm/LB-FT	Nm/LB-FT	Nm/LB-FT
M5 × .8	None used	5.0-6.0/3.7-4.4	7.0-8.0/5.2-5.9
M6 × 1.0	" "	10-12/7.4-9.0	13-15/10-11
M8 × 1.25	" "	23-27/17-20	30-34/22-25
M10 × 1.50	" "	46-53/34-39	58-66/43-49
M12 × 1.75	" "	79-91/58-67	101-116/74-86
M14 × 2.0	" "	126-144/93-106	160-184/118-136
M16 × 2.0	" "	192-220/142-162	245-280/181-207
M20 × 2.5	334-384/246-283	None used	478-550/353-406

STANDARD METRIC BOLTS



Metric Bolts — Identification class numbers correspond to bolt strength — Increasing numbers represent increasing strength.



BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (Nm)	TORQUE (lb-ft)
Injector clamp bolts	M6 x 1.0 x 30	10-12	7-9
Cam follower guide bolts	M8 x 1.25 x 20	23-27	17-20
Camshaft thrust washer bolts	M8 x 1.25 x 20	30-34	22-25
Front cover bolts	M8 x 1.25 x 20	30-34	22-25
Injector control tube assembly bolts	M8 x 1.25 x 20	30-34	22-25
Rocker cover bolts	M8 x 1.25 x 20	23-27	17-20
Valley cover bolts	M8 x 1.25 x 25	23-27	17-20
Camshaft gear bolts	M10 x 1.50 x 40	58-66	43-49
Flywheel housing bolts	M10 x 1.50 x 130	46-53	34-39
Flywheel housing bolts	M10 x 1.50 x 45	58-66	43-49
Rocker arm bracket bolts	M10 x 1.50 x 70	46-53	34-39
*Bearing cap bolts (out) (E)	M12 x 1.75 x 70	90-103	66-76
Connecting rod bolts (E)	7/16"-20	80-95	59-70
Flywheel bolts (E)	M12 x 1.75 x 50	87-100	64-74
Flywheel bolts (E)	M12 x 1.75 x 83	87-100	64-74
*Bearing cap bolts (in) (E)	M14 x 2.0 x 137	140-160	103-118
*Cylinder head bolts (E)	M14 x 2.0 x 160	196	145
*Cylinder head bolts (E)	M14 x 2.0 x 130	196	145
Crankshaft pulley bolt	M20 x 2.5 x 60	334-384	246-283

*Lubricate at assembly with International Compound No. 2 or equivalent.

(E) = Exceptions To Standard

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cylinder Block	
Bore gage setting fixture	J 23059-01
Cylinder bore gage	J 5347-B
Cylinder hone	J 5902-1
Engine stand	J 23935-A
Engine stand adaptor (used with J 23935-A)	J 23013
Valves	
Brush	J 8101
Dial indicator	J 8165-2
Valve oil seal installer	J 28612
Valve spring checking gage	J 25076-B
Valve spring compressor adaptor tool	J 7455-4
Valve spring compressor tool	J 8062
Valve spring tester	J 22738-02
Valve guide repair kit (includes J 33701, J 33702, J 33763)	J 33764
Crankshaft	
Front seal installer	J 29008-A
Front seal remover	J 29007-A
Handle (per J 29010-A)	J 3154-1
Crankshaft pulley remover	J 29025
Rear seal expander	J 29009-A
Rear seal installer	J 29010-A
Piston	
Piston ring compressor	J 29614

SECTION 2

FUEL SYSTEM

CONTENTS

FUEL SYSTEM

A schematic diagram of a typical fuel system is shown in Figure 1. This system includes injectors, a fuel line junction block, fuel manifold (integral with the cylinder head), fuel pump, strainer and filter. A restrictive orifice is located in the fuel return passage in the junction block to maintain the pressure in the fuel system.

Fuel is drawn from the fuel tank through both the fuel strainer and junction block and enters the pump. Leaving the pump under pressure, the fuel flows to the fuel filter via the junction block and then from the filter via the junction block, to the fuel manifold at the front of each cylinder head. The fuel flows to the injectors in the cylinder heads through passages integral with the head and surplus fuel exits at the rear of each head. The surplus fuel is returned through the restrictive fitting in the junction block back to the fuel tank.

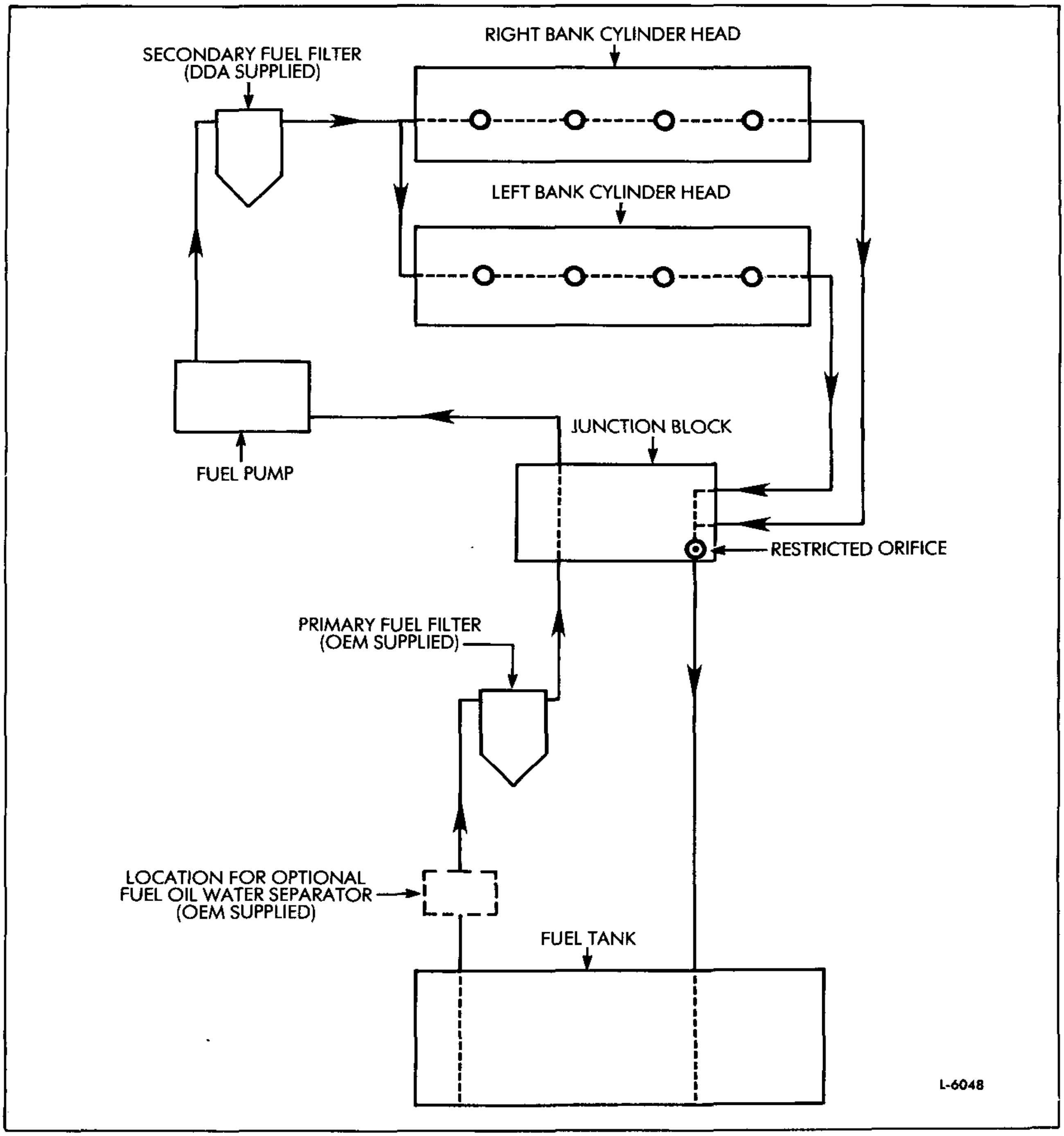


Fig. 1 - Schematic Diagram of Fuel System

FUEL INJECTOR

The injector (Figs. 1 and 2) provides a means of introducing fuel into each combustion chamber. It combines the acts of balancing flow, timing and injection. Fuel flows through supply lines into the drilled passage in each cylinder head. A radial groove around each injector indexes with the drilled passage at the front of the cylinder heads to admit fuel into the injector. A fine mesh screen in the injector provides for final fuel filtration. A fuel crossover drain tube connects the two passages at the rear of the heads and returns the unused fuel to the fuel tank.

The fuel groove around the injector nut is separated by two "O" rings which seal against the cylinder head injector bore. This forms a sealed passage within the cylinder head which becomes the fuel manifold allowing simultaneous fuel supply to all injectors from the engine fuel pump.

The continuous fuel flow around the injector serves to purge air pockets from the fuel system, and as a coolant for the injector.

Combustion required for satisfactory engine operation is generated by injecting a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

Figure 5 illustrates the phases of injector operation during the vertical travel of the injector plunger.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 4 illustrates the fuel metering from no-load to full-load caused by rotation of the plunger in the bushing.

To establish the power output of the engine, injector sets having specific fuel output capacities are used. The fuel output of the various injector types is determined by the helix angle of the plunger and the type of spray tip used. Refer to Fig. 3 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a number stamped on the injector clamp for identification (Fig. 3). The identification number indicates the nominal output and the injector type.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

Operation

Fuel, under pressure, enters the injector through a filter pressed into the injector nut (Fig. 2). Fuel fills that area between the bushing and the nut, in addition to that area under the plunger within the bushing. The plunger operates vertically in the bushing pumping fuel supplied through two funnel-shaped ports in the bushing.

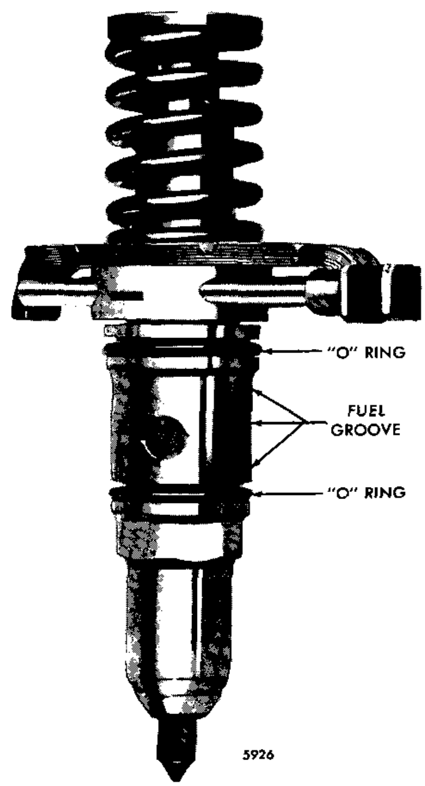


Fig. 1 - Fuel Injector Assembly

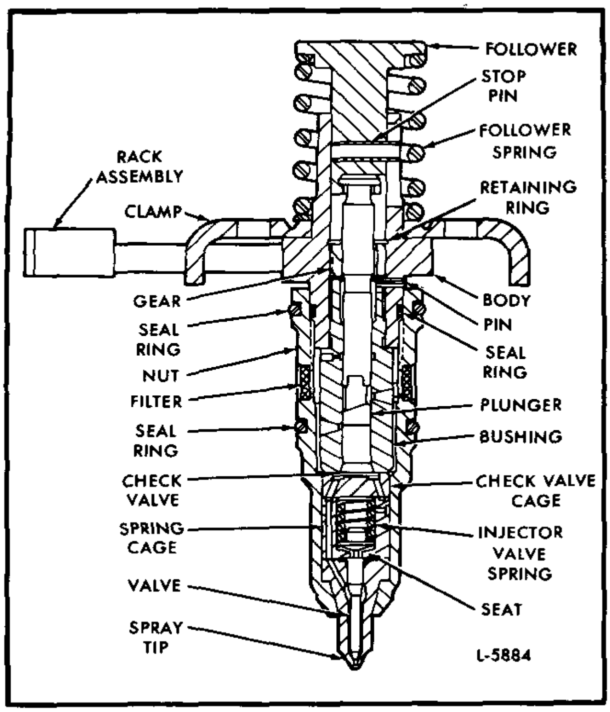


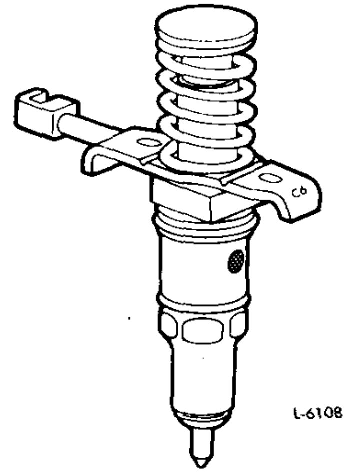
Fig. 2 - Cutaway View of Fuel Injector

Operation

The motion of the injector rocker arm is transmitted to the plunger by the follower which constantly engages the follower spring. In addition to the reciprocating motion, the plunger can be rotated, during operation, by the gear which meshes with the control rack. For metering the fuel, an upper and a lower helix are machined in the lower part of the plunger. As the helix to port relationship is changed by rotating the plunger, the injector output and timing changes to regulate engine performance.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower land of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is pressurized



Injector I.D.	Plunger I.D.	Spray Tip Stamp ∅	Spray Tip Holes	Injector Output Min/Max (CMM)
4A53	53	2	5	53-57
4A40	A4	3	5	42-46
4B45	B4	7	4	48-52
4B55	53	7	4	54-58
4C65*	4C65	4	5	64-68
4A70	4C65	5	6	70-74
4E67	4C65	6	4	65-70
4H60	4C65	8	5	59-63
4B75	B7	8	5	73-77
4J60	J6	7	4	52-56
4K60	K6	7	4	52-56

* Supersedes 4A65 and 4B65

∅ The spray tip stamp (number) appears on the side of the spray tip on the straight section. No other identification appears on the spray tip.

Fig. 3 - Injector Identification Chart

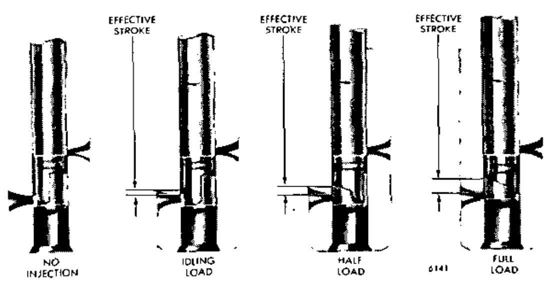


Fig. 4 - Fuel Metering from No-Load to Full-Load

until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced by the plunger through the spray tip orifices causing atomization and delivery into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief hole in the spring cage prevents hydrostatic lock as a result of fuel leaking past the needle into the spring cage.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring.

On the return upward movement of the plunger, the area under the plunger within the bushing is again filled with fuel oil through the ports. Recirculation of fuel through the injector renews the fuel supply in the injector, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system.

Changing the position of the helix, by rotating the plunger, increases or decreases the amount of fuel injected into the cylinder. Figure 4 shows the various plunger positions from no-injection to full-load. With the control rack pulled out all the way to the no-fuel position (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, all of the fuel is forced back out of the bushing and no injection of fuel takes place. With the control rack pushed all the way in (full load), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. The rectangular upper port in the bushing is unique to the Fuel Pincher injector. It serves to provide more precise injection timing.

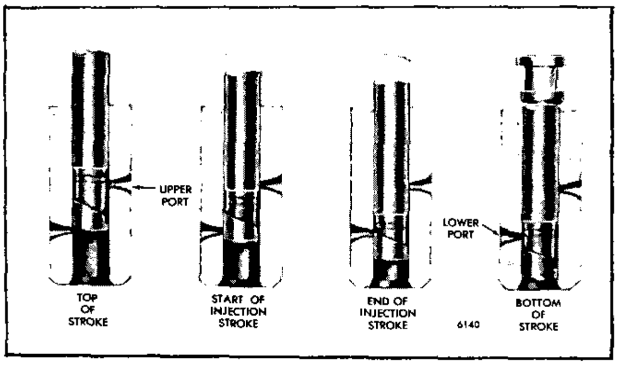


Fig. 5- Phases of Injector Operation Through Vertical Travel of Plunger

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors (see Sec. 2.3).

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Provide the injector repair room with a supply of filtered, compressed air for drying the injector parts after they have been washed. Use wash pans of rust-proof material that are deep enough to permit all of the injector parts to be completely covered by the cleaning solvent when submerged in wire baskets of 16 mesh wire screen. Use baskets because they support the parts and avoid contact with the dirt which settles at the bottom of the wash pans.

Rags should never be used for cleaning injector parts since lint can clog passages of the injector when it is assembled. A lint-free cleaning tissue is recommended for wiping injector parts.

Remove Injector

1. Clean and remove the valve rocker cover.

2. Drain the cylinder head fuel gallery for a minimum of 5 minutes prior to removing the injector. Loosen the fuel line at the junction block allowing fuel to flow faster. Carefully collect the drained fuel to ensure that it does not hit the hot exhaust manifold.

NOTE: All fuel must be removed from the cylinder head before removing the injector to prevent the fuel from entering the cylinder and causing hydrostatic lock or washdown.

3. Remove the two rocker shaft bolts and lift the rocker arms away from the injector and valves.

4. Remove the injector clamp bolts.

5. Lift the injector from its seat in the cylinder head inserting a pry bar in the slots provided in the injector body. Cover the injector hole in the cylinder head to keep out foreign material. Remove carbon from the injector exterior in the area where the tip joins the nut using wire buffing wheel J 7944. Avoid wire brushing the spray holes to prevent damage.

6. Clean the exterior of the injector with clean solvent and dry it with compressed air.

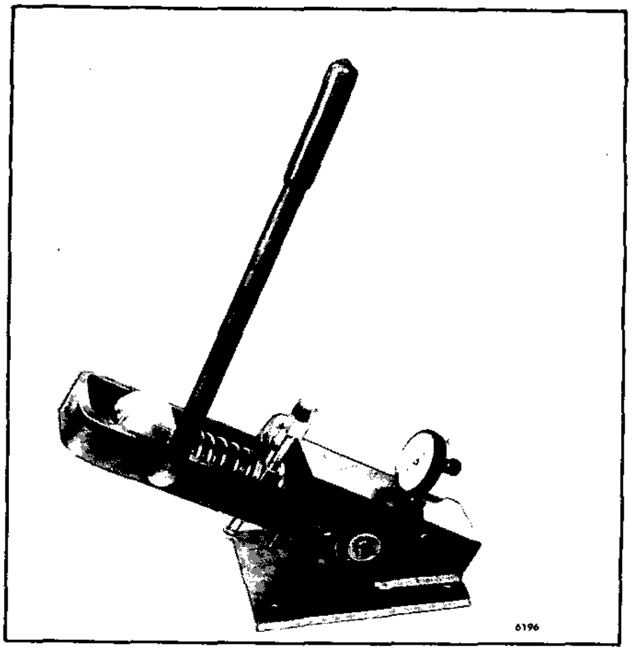


Fig. 6 - Injector in tip concentricity and rack freeness tester J 29584

TEST INJECTOR

CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

If inspection does not reveal any external damage, then perform the following series of tests to determine the condition of the injector to avoid unnecessary repair or replacement. Tests must be performed using injector test oil J 26400 in both the Pop-N-Test fixture J 29531 and the calibrator J 22410.

An injector that passes all of these tests may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct a deficiency.

Identify each injector and record the test results, the pressure drop and the fuel output as indicated by the following tests:

Injector Control Rack, Plunger Movement and Tip Concentricity Test

Place the injector in the tip concentricity and rack freeness tester J 29584 as shown in Fig. 6 with the rack clevis pointing up.

With the injector control rack held in the no-fuel position, operate the handle to depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 7). If the rack falls freely the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing, or nut due to irregular or dirty parts. To test for tip concentricity, rotate the injector slowly while reading the dial indicator. The total reading should be less than .203mm (.008") to pass this test. Irregular parts, dirty parts and misalignment can cause excess tip run-out.

Visual Inspection of Plunger

An injector being tested should have the plunger checked visually under a magnifying glass for excessive wear or a possible chip on the bottom helix.

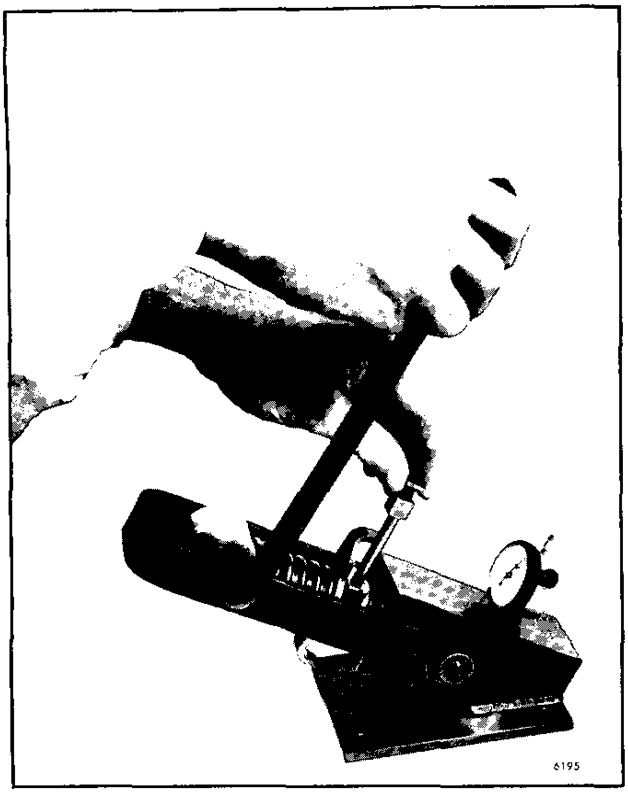


Fig. 7 - Checking Rack for Freeness in Tester J 29584

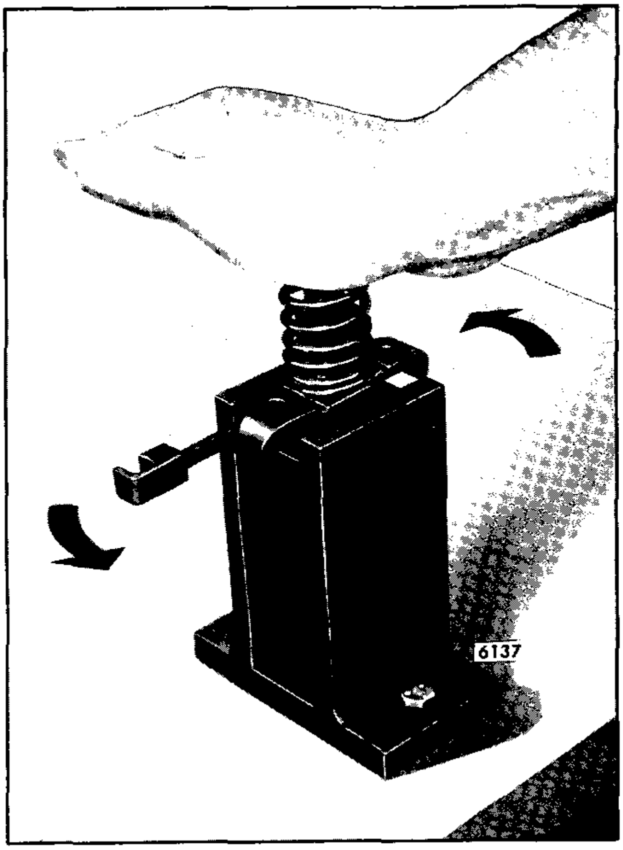


Fig. 8 - Removing Injector Follower

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Remove the plunger from the injector and inspect it as follows:

1. Support the injector, right side up, in holding fixture J 29136 as shown in Fig. 8.

2. Compress the follower spring and rotate the follower slightly until the roll pin lines up with the relief slot in the body.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Using lighted magnification equipment, visually inspect the outside diameter and helix area for undesirable surface conditions such as scoring, nicks, chipping and erosion.

5. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with 500 grit stone. Wash the plunger after stoning it.

6. Reinstall the plunger, follower and spring (refer to Fig. 9). The plunger will fit freely into the gear when properly aligned.

Installing Fuel Injector In Tester J 29531-A

1. Swing out the injector holder and raise the injector clamp lever (see Fig. 10-A).

2. Clean the injector and lubricate the "O" rings with test oil.

3. Install the injector into the injector holder with the rack pointing outward. Rotate the injector 90° counter-clockwise and lower the clamp lever, to properly locate and seal the injector.

4. Swing the injector holder into the test position. (see Fig. 10-B).

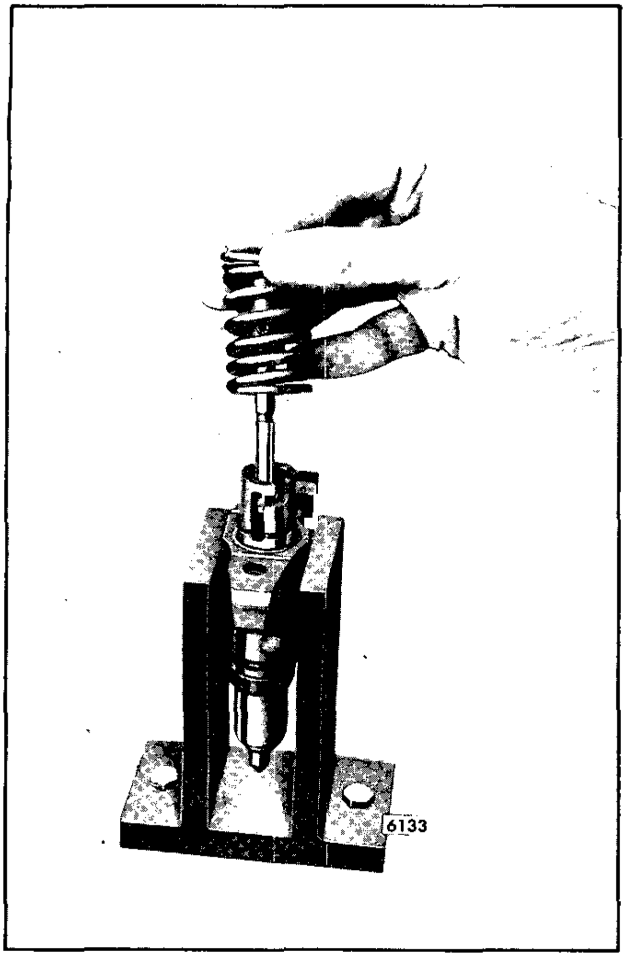


Fig. 9 - Removing or Installing Follower, Plunger and Spring

Purging Air From The System

1. Open the thru-flow shut off valve.

2. Place the pump lever in the vertical position.

3. Move the rocker arm engaging lever to the rear detent as shown (Fig. 10-C).

4. Operate pump lever to produce test oil flow through the injector. When air bubbles no longer pass through the return line, the system is free of air and ready for testing.

Injector Valve Opening and Spray Pattern Test

This test determines the spray pattern uniformity and the relative pressure at which the valve opens and injection begins.

1. Position the injector rack in the full-fuel position.

2. Place the pump lever in the vertical position.

3. Move the rocker arm engaging lever to the forward detent as shown (see Fig. 10-D).

4. Turn the indicator damping valve knob clockwise to the closed position. Open the valve slightly during the test, and adjust for the best reading. This controls the rate of return of the Needle Valve Pop Indicator hand. (The damper is on early models only).

5. Operate the pump lever uniformly and observe the spray pattern produced as well as the pop indicator value.

Some experimentation may be necessary to determine the most effective rate at which the injector should be stroked. The correct rate is the one that produces the highest pop value, to fast or too slow will give low readings.

The highest pop value will be reached just before injection ends. The minimum pop value reading is 135.

NOTE: The reference pop values obtained when pop testing the needle valve injectors is to be used as a trouble shooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the needle valve tip test.

Injector External Leak Test

This test checks for leaks at the nut "O" rings, nut-to-body seal ring, and spray tip.

1. Place pump lever in the vertical position. Move the rocker arm engaging lever to the rear detent position as shown (Fig. 10-E).

2. Close the Thru-Flow valve, but do not overtighten (Fig. 10-E).

3. Operate pump lever and slowly build up to 1380 kPa (2000 psi) on the pressure gauge. Check for leakage.

Injector Pressure Holding Test

This test determines if the body-to-bushing sealing surfaces in the injector are sealing properly and if the proper plunger-to-bushing fit is acceptable.

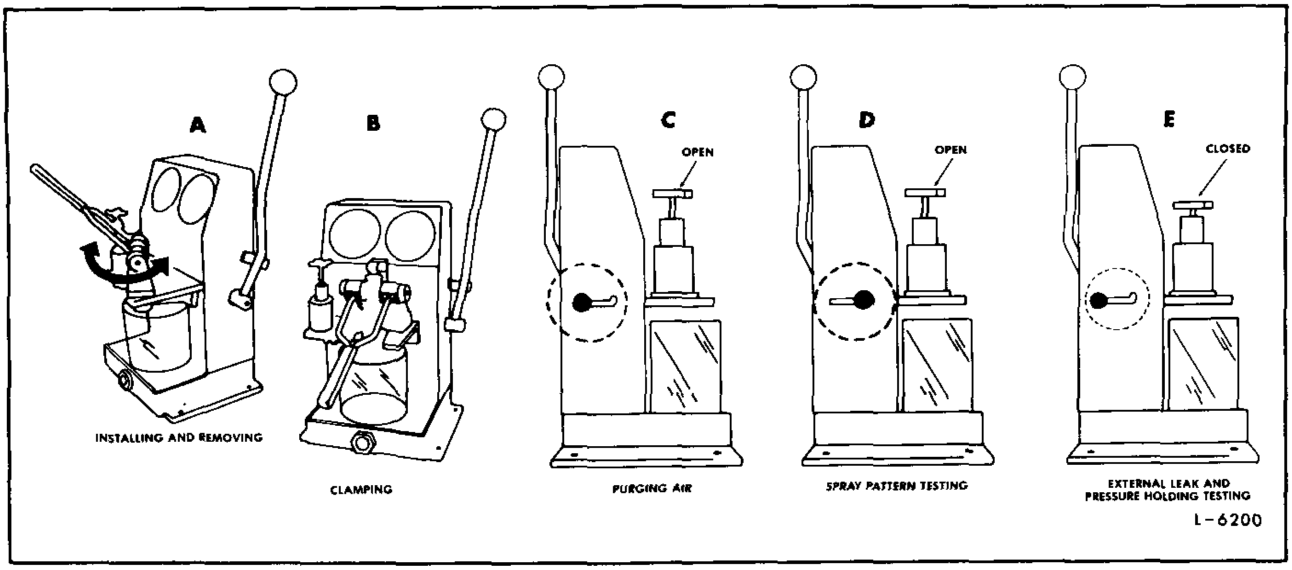


Fig. 10 - Pop-N-Fixture (J 29531) Control Positions

1. With the Thru-Flow valve closed, operate the pump lever until the gauge reads approximately 6895 kPa (1000 psi). Continue to inspect the injector for external leaks.

2. Time the pressure drop from 3 100 to 1 723 kPa (450 to 250 psi). This pressure drop should not occur in less than 15 seconds.

3. Refer to the *Trouble Shooting* charts in Sec. 2.0 if the fuel injector does not pass any of the preceeding tests.

4. If the fuel injector passes all of the above tests proceed with the fuel output test.

Unclamping the Injector

1. Open the thru-flow valve to release pressure in the system.

2. Swing out the injector holder (Fig. 10-A).

3. Raise the injector clamp lever.

4. Rotate the injector clockwise 90° and remove from the injector holder.

Needle Valve Tests

Remove the nut and remove all of the parts below the bushing as outlined under *Disassemble Injector*.

Clean all the carbon from the spray tip seat in the injector nut as outlined under *Clean Injector Parts*.

If the spray pattern test indicated that tip cleaning is necessary, clean the carbon from the tip cavity below the needle valve and orifices as outlined under *Clean Injector Parts*.

Needle Valve Tip Test (using J 29531-A and Tip Test Adaptor J 29531-100)

Remove injector nut and all of the parts below the bushing as outlined under Disassemble Injector

1. With the Tip Test adaptor held securely, assemble the cleaned injector parts including the check valve cage, the injector valve spring, spring seat, spring cage and spray tip assembly.

2. Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the tip test adaptor J 29531-100.

3. Tighten the injector nut.

4. Insert the tip test adaptor and assembled injector parts into the injector holder of tester J 29531 and clamp as if testing and injector assembly.

5. Move the rocker arm engagement lever to the rear position as in Fig. 10-C.

Spray Tip Test

1. Operate the pump lever until no more air is visible passing through the return line.

2. Close the Thru-Flow valve.

3. Operate the pump lever with smooth even strokes (40 strokes per minute) and observe the pressure on the fluid pressure gage. When the needle valve opens allowing injection to occur the pressure gage should read between 18 470 and 23 240 kPa (2700-3400 psi). The opening and closing should be sharp and produce a finely atomized spray.

4. If the valve opening pressure is below 18 470 kPa (2700 psi) and/or atomization is poor, the cause is usually a poor needle seat or a weak injector valve spring.

If the valve opening pressure is within 18 470 - 23 240 kPa (2700-3400 psi) proceed to check for spray tip seat leakage. Actuate the pump handle several times, then hold the pressure at 10 300 kPa (1500 psi) for 15 seconds. Inspect the spray holes for leakage. There should be no fuel droplets although a slight wetting of the end of the tip is permissible.

If the spray tip seat is satisfactory, proceed; check the hold time for a pressure drop of from 13 800 to 10 300 kPa (2000 to 1500 psi). The time should not be less than 20 seconds. If the pressure drops from 13 800 to 10 300 kPa (2000 to 1500 psi) in less than 20 seconds, replace the needle valve and tip assembly.

The needle valve tip test can be performed using the J 23010 Pop-N tester with auxiliary tester J 22640 using sleeve J 22640-32 or using the current self contained needle valve tip tester J 22640-A.

If the needle valve assembly passes the above test, the needle valve lift check can be omitted. To check the needle valve lift, use tool J 9462-01 as follows:

1. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger as shown in Fig. 11.

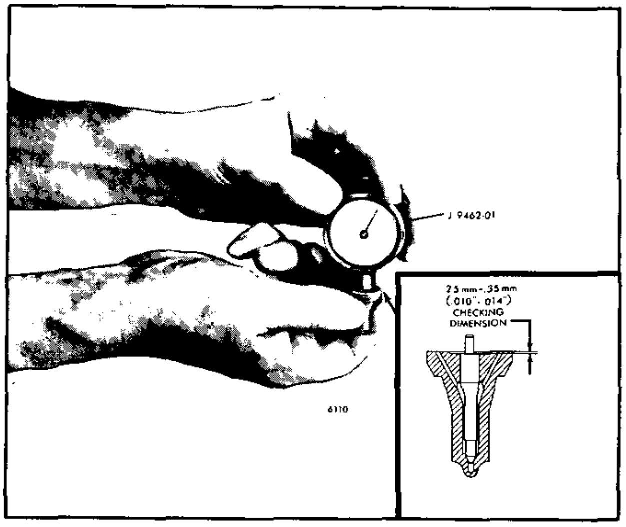


Fig. 11 - Checking Needle Valve Lift

3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .25 mm (.010") to .35 mm (.014"); if it exceeds .35 mm (.014"), the tip assembly must be replaced. If it is less than .25 mm (.010") inspect for foreign material between the needle valve and the tip seat.

4. If the needle valve lift is within the limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly must be replaced.

Reassemble the injector as outlined under *Assemble Injector* and check it in the calibrator.

Fuel Output Test

The injector fuel output test can be performed in the calibrator J 22410 with adaptors.

To check the fuel output operate the injector in the calibrator as follows:

> **NOTE:** Place the cam shift index wheel and fuel flow lever in their respective positions as if testing a 71 series injector. Turn on the test fuel oil heater switch and preheat the test oil to 35°to 40.5°C (95°to 105°F). Install the fuel block J 22410-76 in place of the standard fuel block. Remove the seat assembly J 22410-226

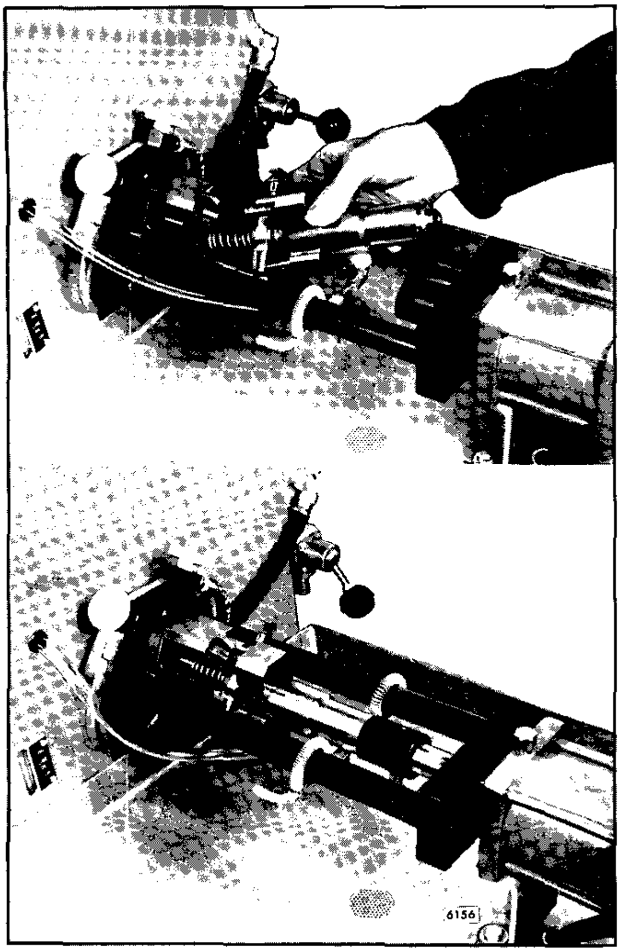


Fig. 12 - Placing Injector and Adaptor in Calibrator.

from the clamp cylinder ram of the calibrator because it is not needed for this test.

1. Place the injector adaptor J 22410-520 between the tie rods and engage it with the fuel block.

2. Place the injector and adaptor assembly J 22410-520 into the adaptor J 22410-562 (cradle handle in horizontal position) as shown in Fig. 12. Clamp the injector into position by operating the air valve.

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

5. After the calibrator has started, and fuel pressure has reached 241 kPa (35psi), set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system. Watch for air in the clear discharge line coming from the tip nose piece.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of the fuel into the vial. The fuel flow to the vial will automatically stop after 1,000 strokes on some machines and 500 strokes on other machines. Three flow tests are necessary to determine accurate injector output. The first test warms the injector and purges the air. The second test usually produces a good accurate reading. The third test should also produce an accurate reading. If the readings from test 2 and test 3 are the same, the reading or output value can be considered accurate. If they are not the same more tests are necessary until repeatability is achieved.

7. Shut the calibrator off (the calibrator will stop in less time if the injector rack remains at full-fuel).

8. Study the results and determine whether the injector output is correct. Refer to Fig. 3 for specific injector output. If the output is not correct, refer to the Trouble Shooting Charts and Shop Notes in Section 2.0 for the cause and remedy.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator J 22410 and the pop stand J 29531, Fig. 13.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in the injector holding fixture J 29136 as shown in Fig. 9.

> **NOTE:** Whenever a fuel injector is disassembled, discard the external seal rings and replace with new seal rings.

2. Compress the follower spring slightly and rotate the follower counter clockwise until the roll pin aligns with the release slot in body.

3. Remove the follower, plunger and spring as an assembly.

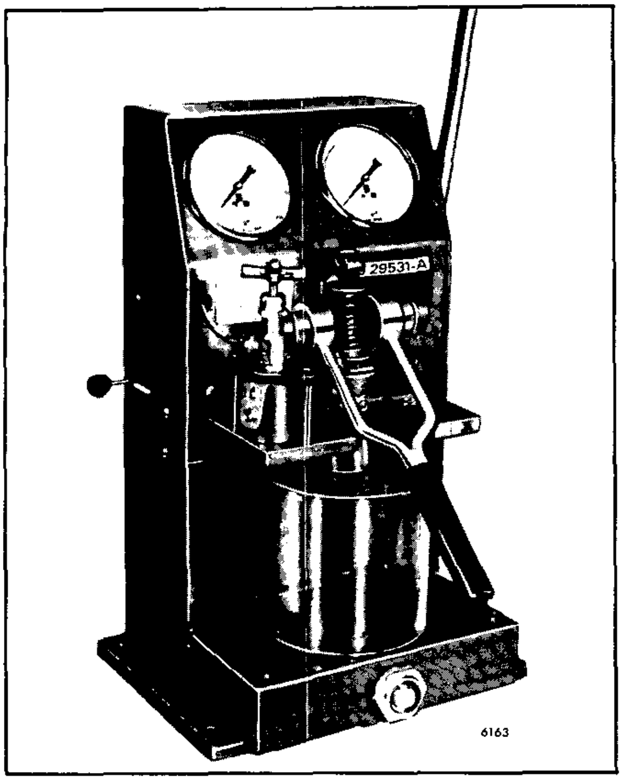


Fig. 13 - Injector Installed in Tester J 29531

4. Invert the injector and, using nut wrench J 29137 loosen and remove the nut from the injector body.

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut using a plastic or wood block so as not to damage the tip.

6. Lift the bushing straight out of the injector body.

7. Remove the rack and gear.

a. Align the missing tooth of the gear with the retaining pin.

b. Turn the body upside down and catch the gear in your hand as it falls out of the body.

c. Withdraw the injector control rack from the injector body.

Clean Injector Parts

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable cleaning solvent and dry them with clean, filtered compressed air. *Do not use textile waste or rags for cleaning purposes.* Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Keytone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 24838.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm.

> **NOTE:** Do not buff excessively. *Do not use a steel wire buffing wheel. Do not buff the spray hole area or the spray tip holes may be distorted. Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices in an ultrasonic cleaner.*

After ultra sonic cleaning, wash the spray tip in clean solvent and dry it with compressed air.

Carefully insert carbon remover tool J 29575-1 in the injector nut. Turn it in a clockwise direction to remove the carbon deposits on the flat spray tip seat. Remove the carbon deposits from the lower tapered end of the injector nut with carbon remover J 29575-2 in the same manner. Use care to prevent removing any metal or setting up burrs on the spray tip seat.

Wash the injector nut in clean solvent and dry it with compressed air. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious lubricating oil dilution problem. *Keep the plunger and bushing together as they are mated parts.*

After washing, submerge all the injector parts in a clean receptacle containing clean injector test oil. *Keep the parts of each injector assembly together.*

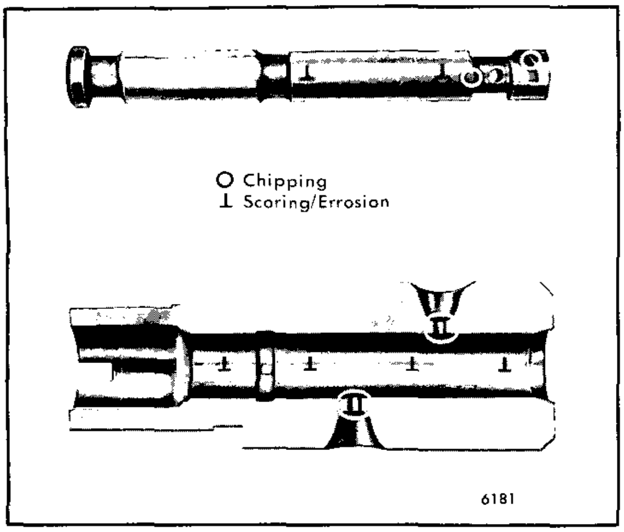


Fig. 14 · Injector Plunger and Bushing

Inspect Injector Parts

Inspect the injector follower and pin for wear. Refer to Section 2.0.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

The injector follower spring 4.07 mm (.160") diameter wire has a free length of approximately 47.36 mm (1.865") and should be replaced when a load of less than 435.0 N (98 lbs) will compress it to 31.7 mm (1.248").

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in additional fuel consumption and contamination of the lubricating oil.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear (Fig. 14). Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Slip the plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted. Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.*

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Use reamer J 29575-1 and resurface the seat if necessary or replace the nut or tip if it is severly damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the injector parts. Examine the sealing surfaces with a magnifying glass. The slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart.

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

Before reinstalling used injector parts, lap all of the sealing surfaces. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

Part Name	Minimum Thickness
Spray Tip (shoulder)	5.11 mm (.201")
Check Valve Cage	5.99-6.04 mm (.236"-.238")
Check Valve	6.1 mm (.024")
Valve Spring Cage	15.35 mm (.604")

MINIMUM THICKNESS (Used Parts)

Lapping Injector Parts

Lap the sealing surfaces.

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively* (refer to the chart on minimum thickness).

5. When the part is flat, wash it in clean solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in clean solvent and dry it with compressed air.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

Assemble Injector

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean and wetted with test oil.

Assemble Rack and Gear

Note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, threaded end up, and slide the rack through the hole in the body. Look into the

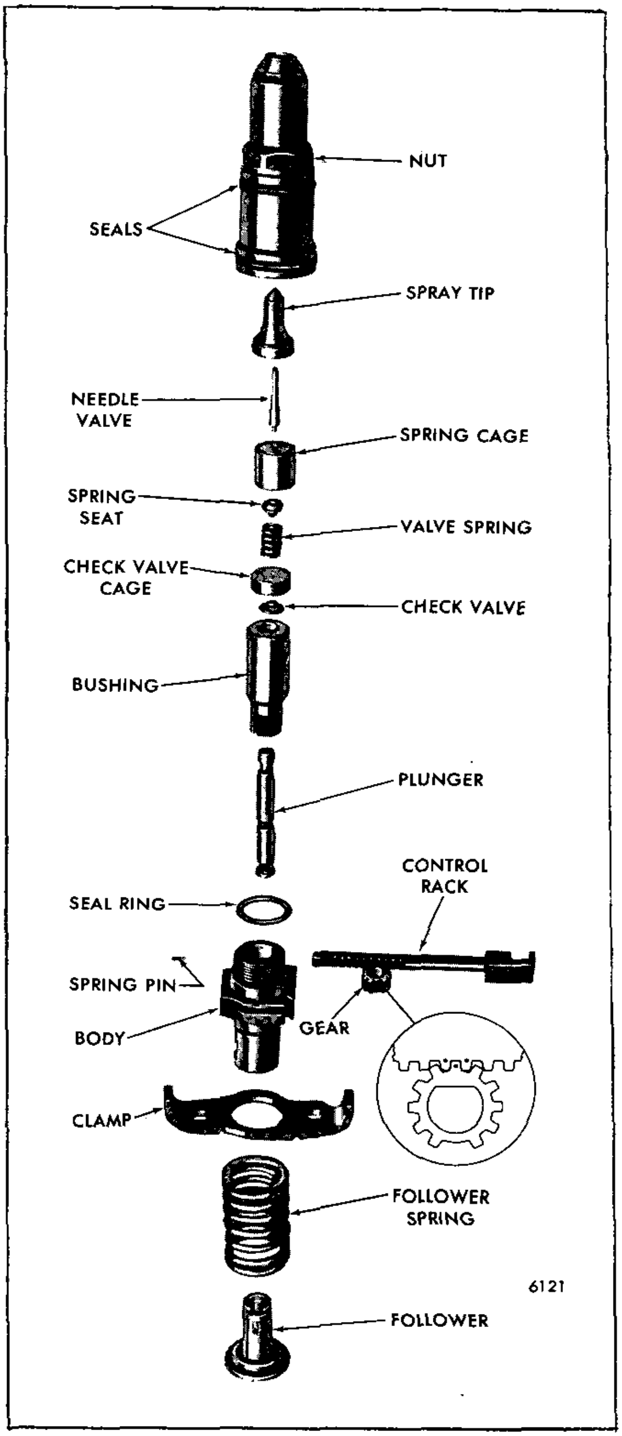


Fig. 15 · Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

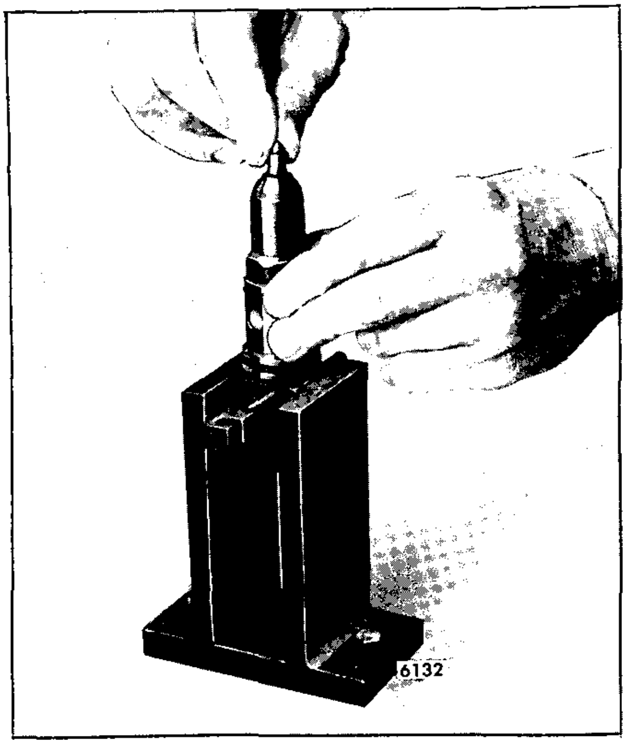


Fig. 16 - Tightening Injector Nut by Hand while Rotating Injector Spray Tip

body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack as shown in Fig. 15.

3. If necessary install a new spring pin in the injector body to retain the gear.

4. Align the locating slot in the bushing with the pin in the injector body, then slide the end of the bushing into place.

Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 15 and assemble the parts as follows:

1. Support the injector body, bottom end up, in injector holding fixture J 29136.

2. Place a new seal ring in the seal ring groove of the body. Wet the seal ring with test oil.

3. Place the check valve centrally on the top of the

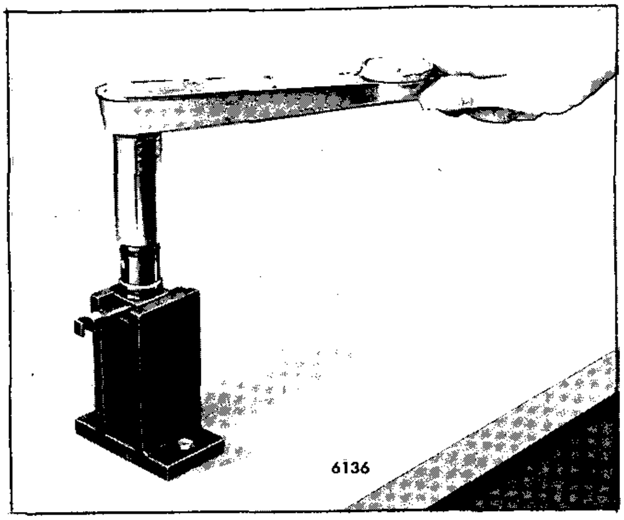


Fig. 17 - Tightening Injector Nut with Nut Wrench J 29137 and fixture J 29136

bushing. Then place the check valve cage over the check valve and against the bushing.

4. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

5. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

6. Insert the needle valve, tapered end down, into the spray tip. Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

7. Lubricate the threads in the injector nut with test oil and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger (Fig. 16) while threading the nut on the injector body. Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

8. Use injector nut wrench J 29137 and a torque wrench (Fig. 17) to tighten the injector nut to 95-108 Nm (70-80 lb-ft) torque.

NOTE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in the subsequent injector overhaul. Over tightening can also cause a tight rack.

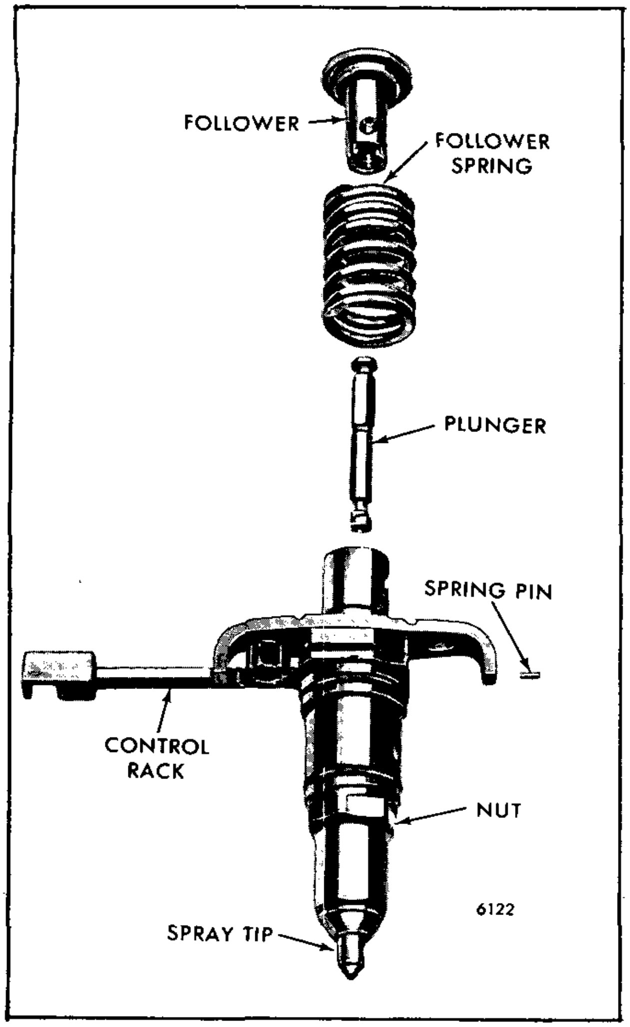


Fig. 18 · Injector Plunger, Follower and Relative Location of Parts

Assemble Plunger and Follower

1. Refer to Fig. 18 and slide the head of the plunger into the follower.

2. Invert the injector in the injector holding fixture (follower end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Align the flat side of the plunger with the guide slot in the injector body. Align the spring pin in the follower with the release slot in the injector body. Press down on the follower while rotating clockwise (Fig. 8) until it contacts the guide slot and then release the follower.

Check Spray Tip Concentricity and Rack Freeness

To assure correct alignment check the concentricity of the spray tip as follows:

1. Place the injector in the rack freeness and tip concentricity gage J 29584 and adjust the dial indicator to zero.

2. Rotate the injector 360° and note the total run-out as indicated on the dial.

3. If the total run-out exceeds 0.2 mm (.008"), remove the injector from the gage. Loosen the injector nut, rotate the spray tip and tighten the nut to 95-108 Nm (70-80 lb-ft) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, inspect and clean the injector parts.

4. After depressing the follower, release it slowly, checking to see if the rack falls freely when moved in and out by hand. If the rack hangs up, disassemble to clean and align the parts. Reassemble and test the injectors.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector.*

> **NOTE:** The spray tip should be checked for pop pressure and atomization before assembly. The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 29124-4, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Lubricate the "O" rings with engine oil. Be sure that the larger external "O" ring is installed in the top seal ring groove in the injector nut, and that the smaller external "O" ring is installed in the lower seal ring groove. Install the injector in the engine as follows:

1. Insert the injector into the injector tube.

2. Rotate the injector rack control level over so that it registers with the injector rack.

3. Clamp the injector in place with the two 6 mm bolts.

Tighten the bolts to 10-12 Nm (7 - 9 lb-ft) torque. Do not over torque these bolts.

NOTE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind causing the engine to stall or hunt.

NOTE: Keep the plunger and bushing together as they are mated parts.

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed with a ring seal and upset into the flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

NOTE: It is recommended that the injector tube be replaced with new parts at the time of engine overhaul.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 29124 as follows:

1. Remove, disassemble and clean the cylinder head as outlined in Section 1.2.

2. Place the injector tube installer J 29124-17 in the injector tube. Insert the pilot J 29124-2 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer Fig. 1.

3. Tap on end of pilot J 29124-2 using a brass hammer or fiber mallet. Carefully drive and lift the injector tube, installer and pilot from the cylinder head. Then remove the injector tube "O" ring located in the cylinder head casting at the upper end of the injector tube bore.

Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove any dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Excess material in the form of a small copper ring will be left at the lower end of the injector tube counterbore after the injector tube has been removed. This copper ring will have to be removed using a suitable sharp pointed tool.

1. Lubricate the Viton injector tube sealing "O" ring with engine oil and place it in the groove of the cylinder head injector tube counterbore.

NOTE: DO NOT lubricate the outside of the injector tube or inside the cylinder head injector tube bore to facilitate installation of the tube. Lubricant will cause the tube to turn during reaming or rolling operations possibly damaging the injector tube or reamers.

2. Install the injector tube on the injector tube installer J 29124-17 (Fig. 2). Next, insert the pilot J 29124-2 through the small opening of the injector tube. Thread pilot J 29124-2 into the injector tube installer J 29124-17. Install the injector tube installer, injector tube, and pilot into the injector bore.

3. Tap the injector tube and tool assemblies into the injector bore and carefully drive into place using a brass hammer or fiber mallet as shown in Fig. 2.

4. Tighten the injector tube holder bolts.

5. Do not exceed 10-12 Nm (7-9 lb-ft) torque on the hold down bolts. After the holder bolts have been tightened, tap the tube installer once more to ensure

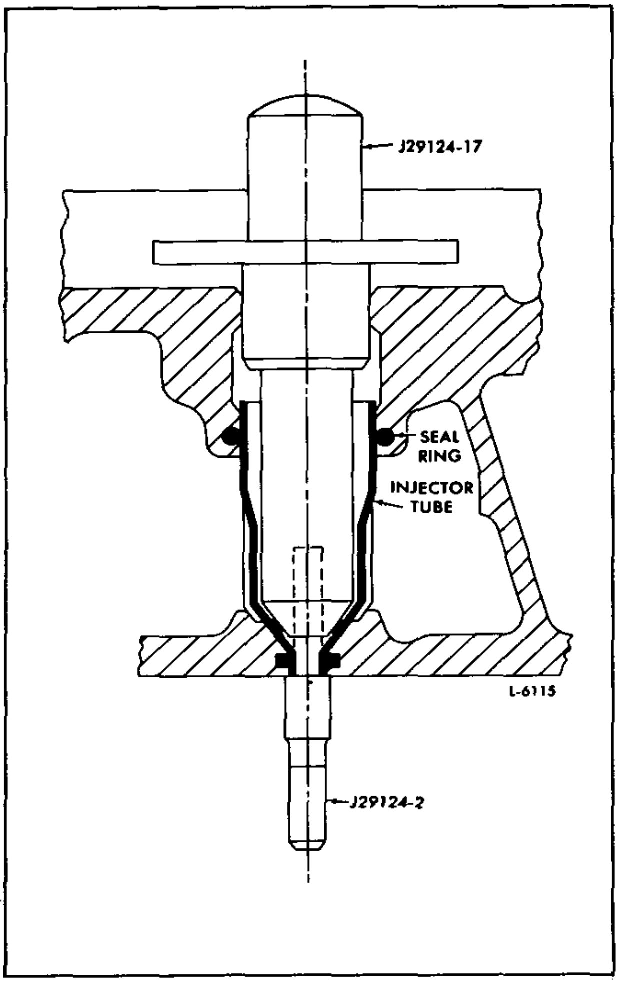


Fig. 1 - Removing Injector Tube

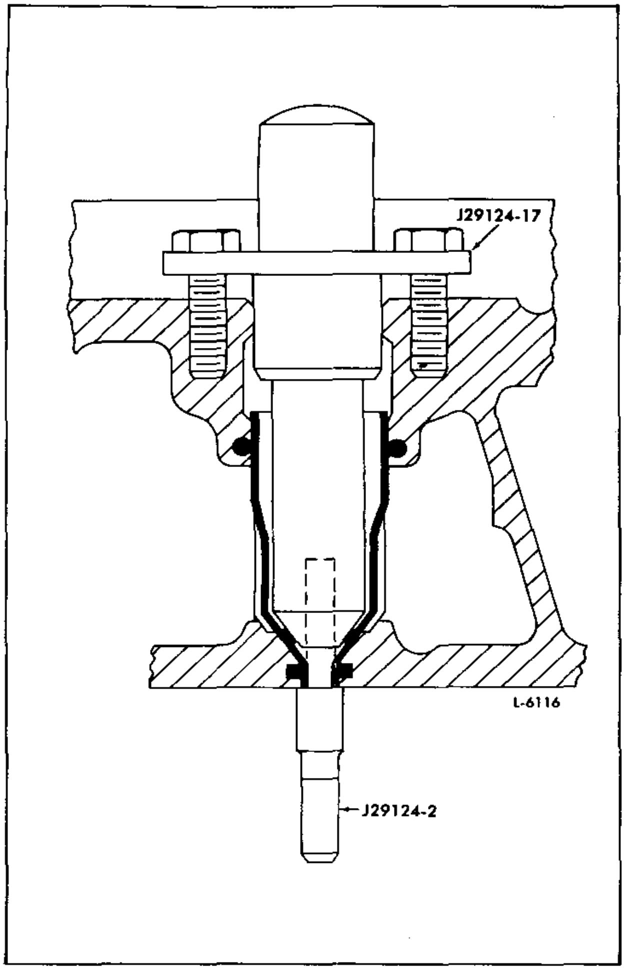


Fig. 2 - Installing Injector Tube

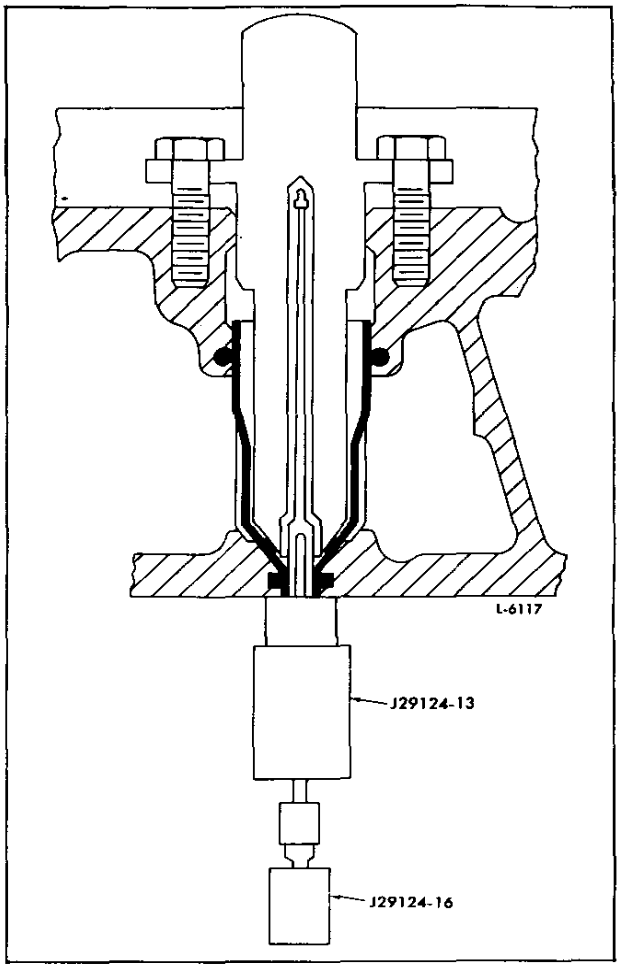


Fig. 3 - Rolling End of Injector Tube

the tube is properly seated and recheck the tube holder bolts for tightness.

6. Remove pilot J 29124-2 and installer J 29124-17 from the injector tube.

> **NOTE:** Due to the "stack-up" of tolerances involved, there may be a few occasions when the tube tip will close in and pinch the pilot. If this situation is encountered, use pliers on the pilot handle (knurled portion only) to facilitate its removal.

Roll Injector Tube

With the injector tube properly positioned in the cylinder head, roll the lower end of the injector tube as follows:

1. Install the roller J 29124-13 in the adaptor J 29124-16. Position the roller assembly into the injector tube small end. Use a 3/8" drive speedhandle and the adaptor J 29124-16 to turn the roller drive as shown in Fig. 3.

> **NOTE:** Put a few drops of light engine oil on the small rollers of the roller assembly for lubrication before inserting it into the injector tube small end. When debris becomes apparent on the small rollers of the roller assembly, cleaning of the rollers in a solvent will be necessary.

2. The roller J 29124-13 must be held perpendicular to the firedeck of the cylinder head when being rotated. Turn the roller clockwise applying a slight pressure to the speedhandle until it forces the small rollers firmly against the inside of the lower end of the injector tube.

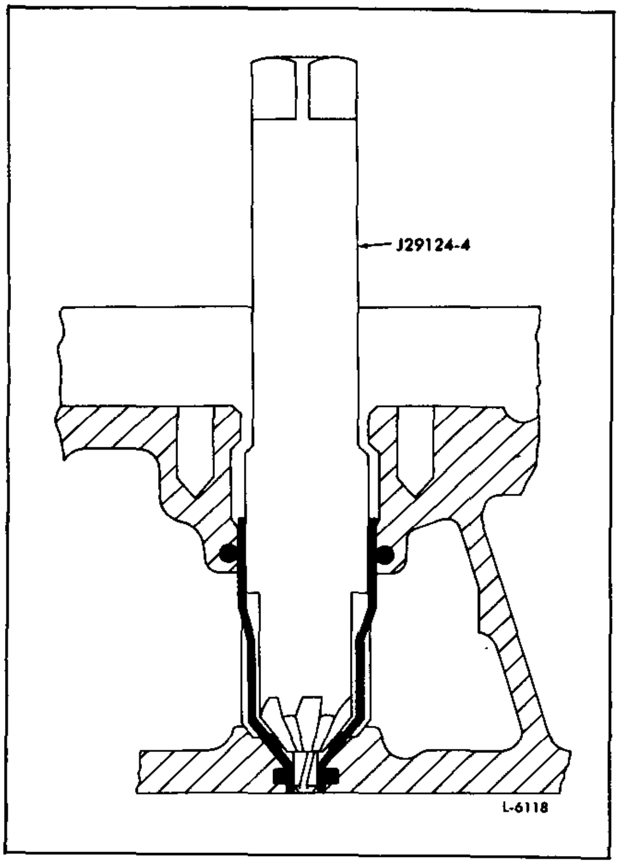


Fig. 4 - Reaming Injector Tube for Injector Body Nut and Spray Tip

3. Continue applying pressure and rotating the tool clockwise to roll the end of the tube firmly against the cylinder head casting tube opening.

4. After several *clockwise* rotations of the tool, turn the roller drive counterclockwise and remove it from the tube end by pulling it outward.

5. Check the small inside diameter of the injector tube using the go, no-go gage J 29124-11. When the tube (small I.D.) has been rolled to the proper dimension, only the ground end of the go, no-go gage will fit into the injector tube. If the small I.D. has been rolled too large, the second ground step on the gage will also go into the tube. If the small I.D. of the tube has been rolled too large, the injector hole tube will have to be replaced.

6. If the first step on the go, no-go gage will not insert into the tube, the roller J-29124-13 will have to be reinstalled and the tube rolled to a larger dimension. Repeat sequence until the small I.D. of the injector tube is rolled to the proper dimension.

NOTE: Care should be taken to ensure the tube small I.D. is not rolled too large during the rolling operation. When the rolling operation has been completed, the injector tube holder J 29124-17 must be removed before the reaming operation.

Ream Injector Tube

After an injector tube has been installed in a cylinder head, and the tube small I.D. has been rolled it must be finished in two operations. First, it must be *hand reamed* to receive the spray tip and provide a good seating surface for the bevel or the lower end of the injector nut. Second, the tube must be *spot-faced* to remove excess stock at the lower end of the injector tube.

NOTE: The reamer should be turned in a *clockwise direction* only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the (sharpened) cutting edges of the flutes.

1. The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder

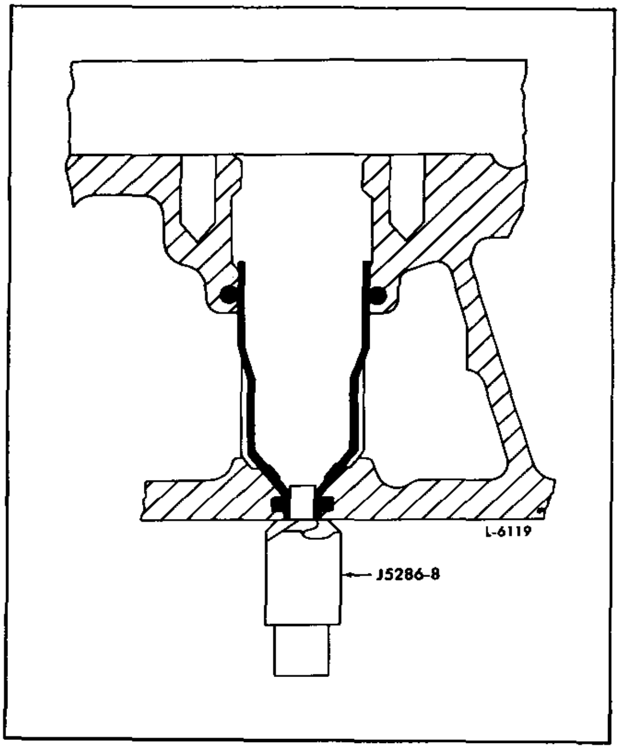


Fig. 5 - Refinish Injector Tube Tip

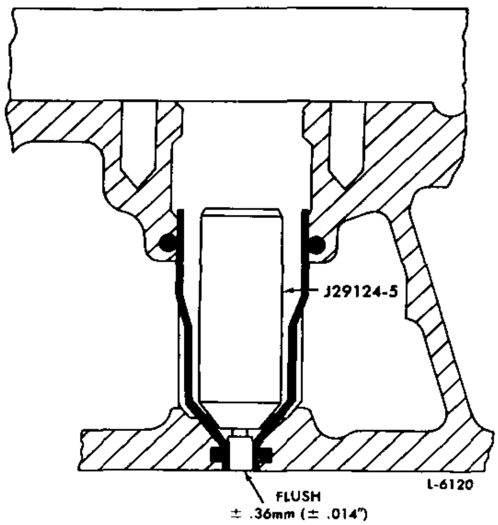


Fig. 6 - Measuring Relationship of Gage to Cylinder Head Fire Deck

pressures and properly position the injector tip into the combustion chamber. Carefully install the reamer J 29124-4 into the injector tube until the smaller set of flutes contact the tube end as shown in Fig. 4.

NOTE: The injector tip protrusion into the combustion chamber should measure from 2.85-3.85 mm (.122"-.152").

2. Using a (12 pt. 23mm) socket and rachet or speedhandle, make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips, and look at the small I.D. of the tube and bevel seat to see what portion of the tube's I.D. and seat has been cut.

3. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress. After the small I.D. of the injector tube has been fully reamed, the excess injector tube material on the firedeck surface of the cylinder head will have to be removed.

4. Remove excess stock.

a. With the cylinder head firedeck in a workable position, insert the pilot J 5286-8 tube tip refinisher into the small hole of the injector tube as shown in Fig. 5.

b. Then, using a (12 pt. 15 mm) socket and speedhandle, turn the refinisher to remove excess stock so that the lower end of the injector tube is from flush to ,13 mm (.005") below the firedeck surface of the cylinder head.

c. Remove the chips from the injector tube. Then, using a protrusion gage J 29124-5 as a gage, continue the injector tube beveled seat reaming operation until the gage end is from flush to ±.36 mm (±.014") with the firedeck surface of the cylinder head as shown in Fig. 6. A sled gage with a dial indicator is used to measure the protrusion gage dimension.

FUEL PUMP (GEAR TYPE)

The positive displacement gear-type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return line.

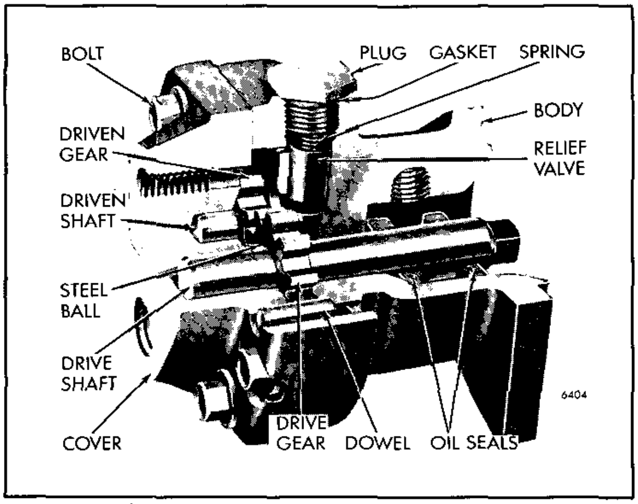


Fig. 1 - Typical Fuel Pump Assembly

The fuel pump is attached to an adaptor mounted on the governor weight housing and is driven through a drive coupling by the governor weight shaft (Fig. 2).

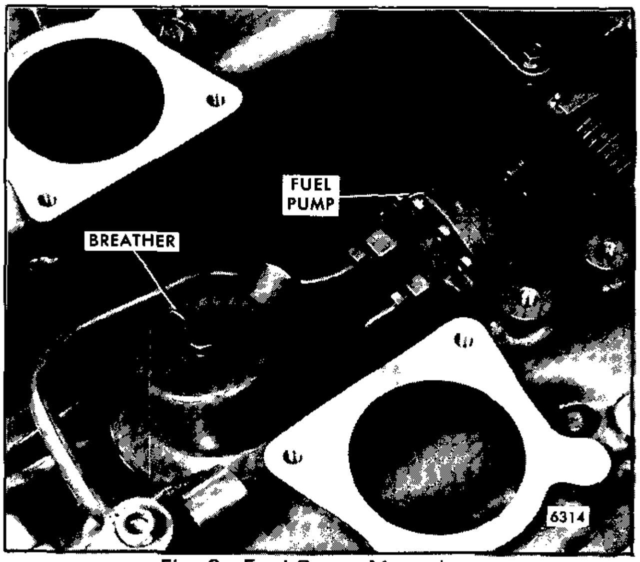


Fig. 2 - Fuel Pump Mounting

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3). Recesses are also provided at the inlet and outlet positions of the gears. The small hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the governor (Fig. 1). The oil seals are installed with the lips of the seals facing each other. A small hole "E" (Fig. 3) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

Some fuel oil seepage by the fuel pump can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

The drive and driven gears are a line-to-line to a .025 mm (.001") press fit on their shafts. The drive gear drive gear is provided with a gear retaining ball to locate the gear on the shaft.

A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 448 kPa (65 psi).

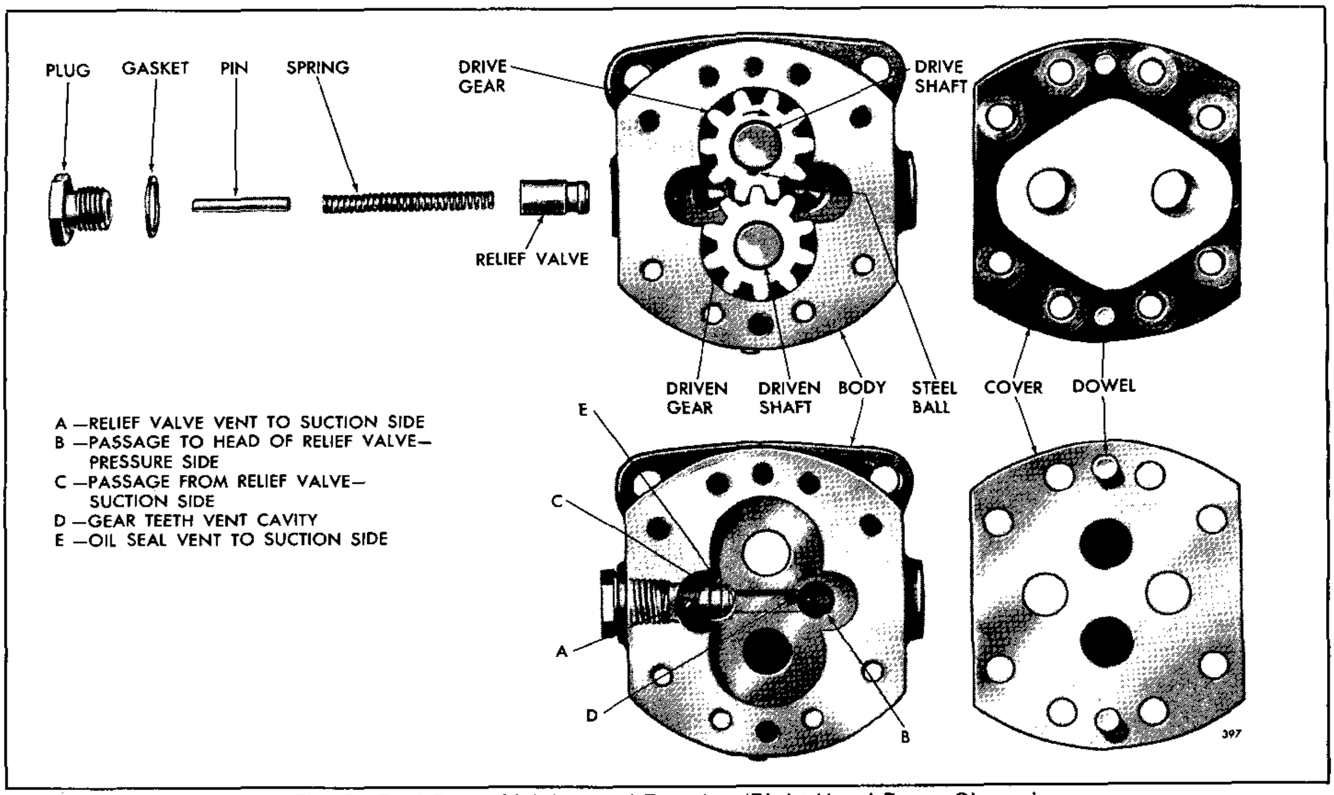


Fig. 3 - Fuel Pump Valving and Rotation (Right Hand Pump Shown)

Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 448 to 517 kPa (65 to 75 psi).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold (see Section 13.2).

Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Disconnect the drain tube, if used, from the fuel pump.
3. Remove the three pump attaching bolts and withdraw the pump from the mounting adaptor on the governor housing.
4. Check the drive coupling and, if broken or worn, replace it with a new coupling.

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 (Fig. 4), refer to Figs. 1 and 6 and disassemble the pump as follows:

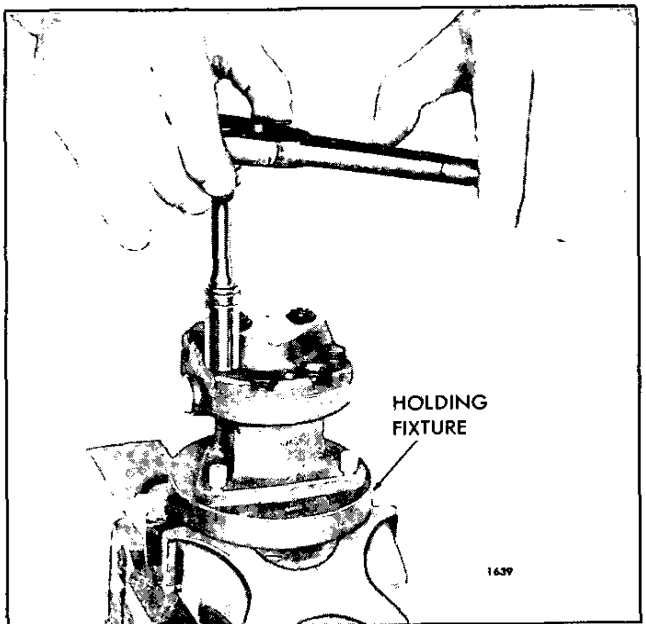


Fig. 4 - Removing Fuel Pump Cover

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.
3. Press the drive shaft just far enough to remove the steel locking ball. Then, invert the shaft and gear assembly and press the shaft from the gear. *Do not misplace the steel ball* . Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.
4. Remove the driven shaft and gear as an assembly from the pump body. *Do not remove the gear from the shaft* . The driven gear and shaft are serviced only as an assembly.
5. Remove the relief valve plug and copper gasket.
6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.
7. If the oil seals need replacing remove them with oil seal remover J 1508-13 (Fig. 5). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals. Observe the old seals to permit installation of the new seals in the same position.

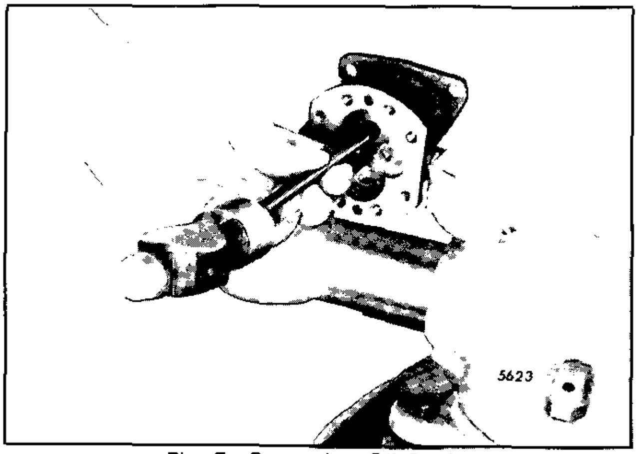


Fig. 5 - Removing Oil Seals

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts, if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Assemble Fuel Pump

Refer to Figs. 1, 3 and 6 and assemble the pump as follows:

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:
   a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face the shoulder on the tool.
   b. With the pump body supported on wood blocks (Fig. 7) insert the pilot of the installer handle in the pump body so that the seal starts straight into the pump flange. Then, drive the seal in until it bottoms.
   c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing away from the adaptor. Then, insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 8) until the shoulder of the adaptor contacts the pump body. Thus, the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.
2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2"-20 plug to 24-33 N·m (18-24 lb-ft) torque.
3. Install the pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining detent. Then, place the ball in the detent and press the gear back until the end of the slot contacts the ball.
4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals (Fig. 9).

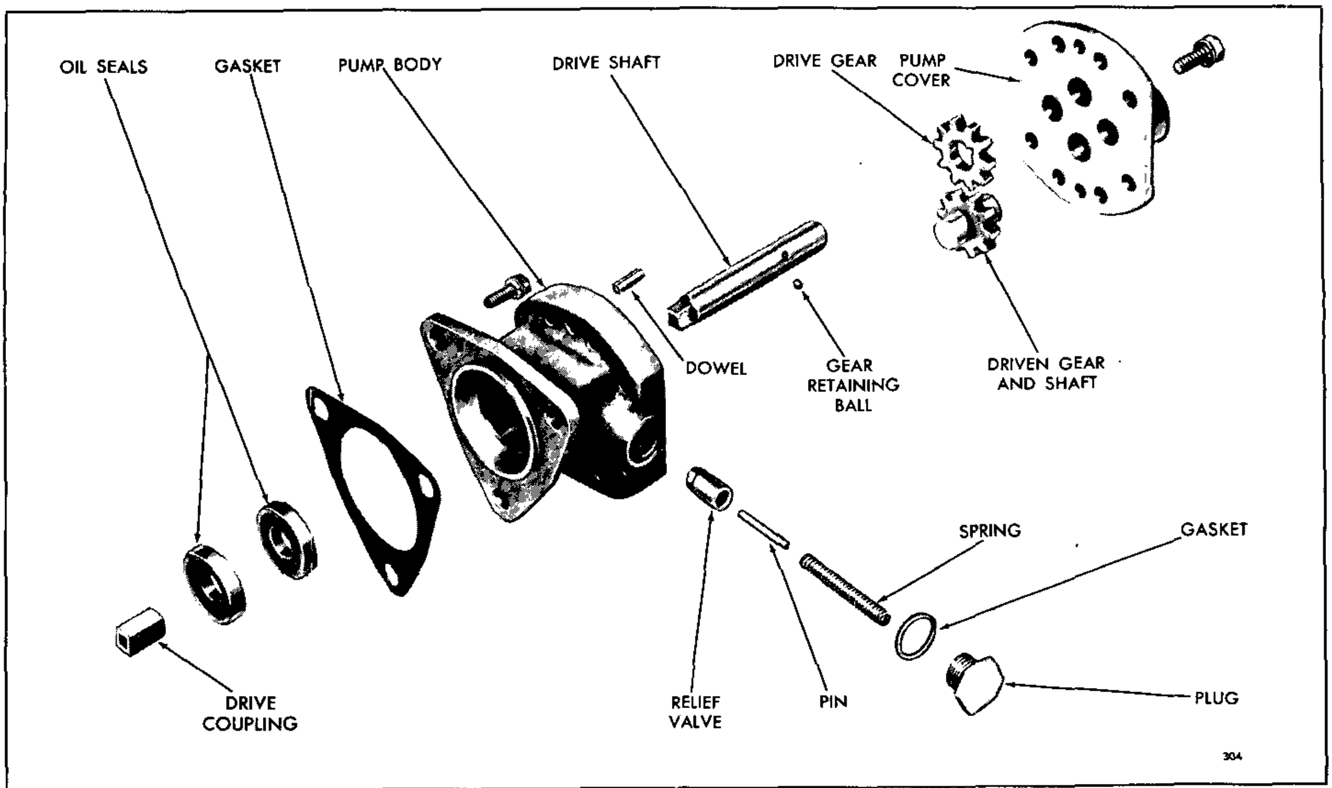


Fig. 6 - Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

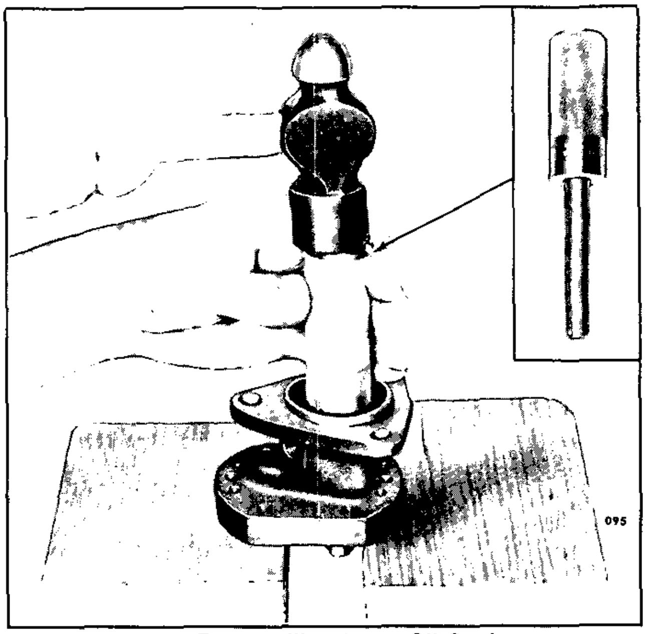


Fig. 7 - Installing Inner Oil Seal

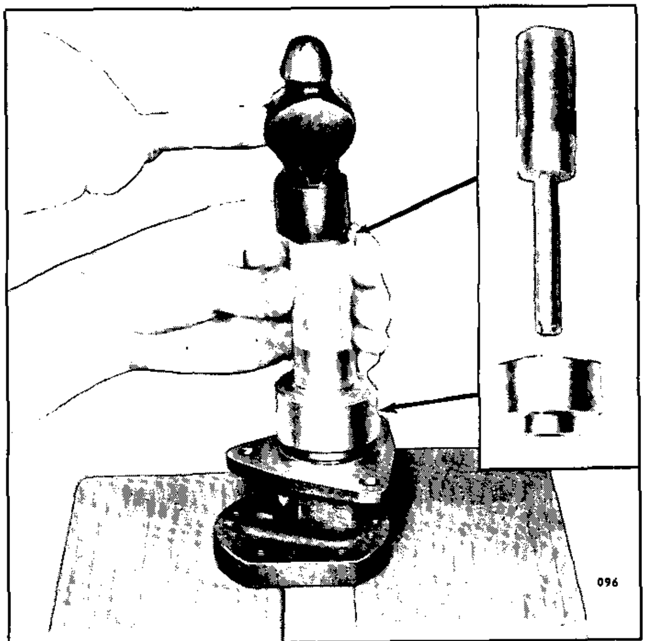


Fig. 8 - Installing Outer Oil Seal

5. Place the driven shaft and gear assembly in the pump body.

The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

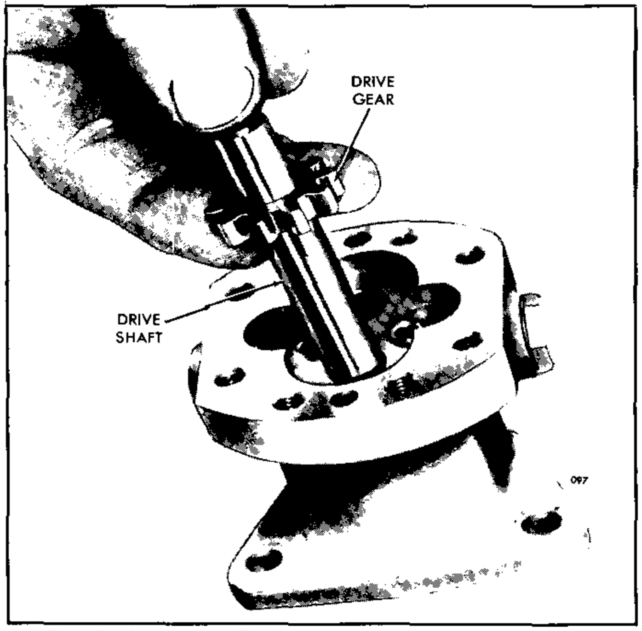


Fig. 9 - Installing Fuel Pump Drive Shaft and Gear Assembly

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then, place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

NOTICE: The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.
9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.
10. Install new plain 1/8" pipe plugs in the upper unused drain holes.
11. If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

1. Affix a new gasket to the pump body mounting flange and locate the pump drive coupling over the square end of the fuel pump drive shaft.
2. Install the fuel pump on the adaptor and secure it with three bolts.
3. Connect the inlet and outlet fuel lines to the fuel pump.
4. Connect the fuel pump drain tube, if used, to the pump body.
5. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine. This will prevent the possibility of pump seizure upon initial starting.

FUEL FILTER (SPIN-ON)

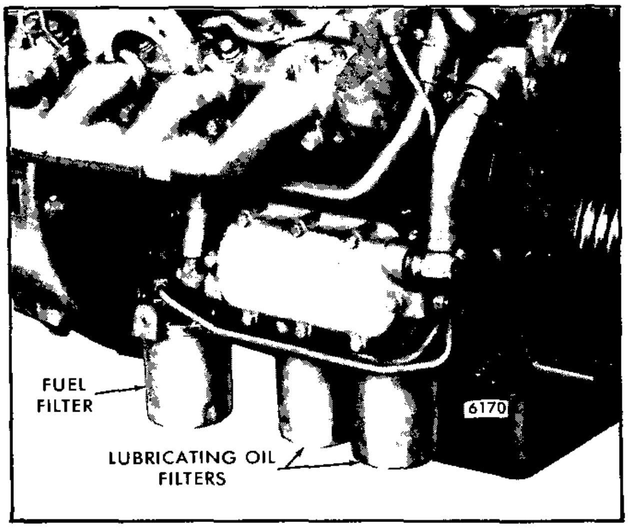


Fig. 1 - Fuel Filter Mounting

A *spin-on type* fuel filter is used on the Fuel Pincher engine. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "*Secondary*" *is cast on the fuel filter cover* for identification.

No drain cocks are provided on the spin-on filters. Residue may be removed by turning off the filter and inverting it. Refill the filter with clean fuel oil before reinstalling it.

Filter Replacement

Using a suitable band wrench or oil filter wrench J 22775 remove and replace the filter as follows:

1. Unscrew the filter and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the gasket lightly with clean fuel oil.

3. Install the new filter turning it until it contacts the gasket, then turn for an additional one half turn.

4. Start the engine and check for leaks.

Limiting Speed Mechanical Governor

The limiting speed mechanical governor (Figs. 1 and 2), performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum operating speed of the engine.

The double-weight governor, identified by the letters D.W.-L.S. stamped on the governor name plate is attached to the engine block between the cylinder banks. One end of the governor weight shaft is pressed into a gear which is driven by the cam gear to provide a means of driving the governor. The other end of the shaft is used to drive the fuel pump.

The governor consists of four basic sub-assemblies: a cover and lever assembly, governor housing, spring housing, and a weight and shaft assembly. A 12 volt pull type solenoid shutdown is mounted on the governor.

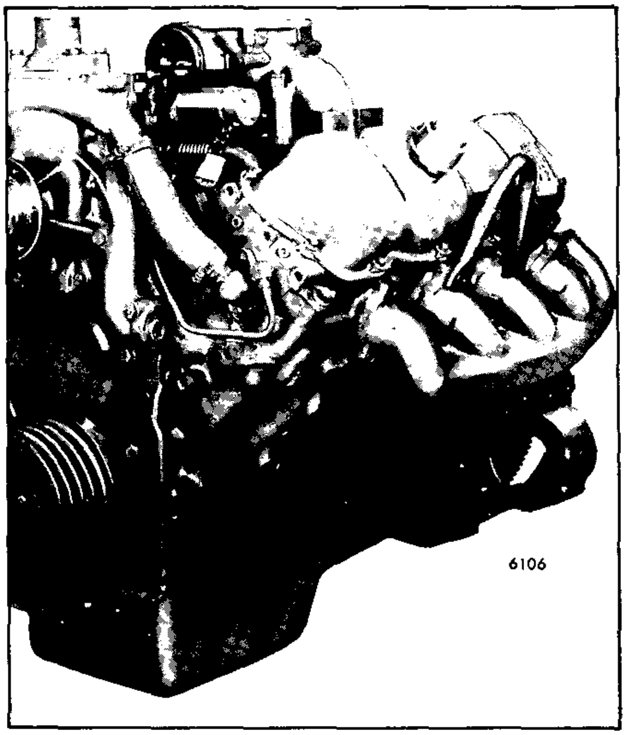


Fig. 1 - Governor Mounted on Engine

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the **RUN** position, the stop lever allows the fuel injector racks to move near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever bears against the governor spring cap while the other end provides a moving fulcrum on which the differential lever pivots.

In the low speed range, the centrifugal force of the low speed weights and the high speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of both pairs of weights compresses the low speed spring until the low speed weights have reached the limit of their travel, at which time the low speed spring is fully compressed and the spring cap is within .07 mm (.003") of the high speed spring plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low speed spring and the low speed weights are not exerting enough force to overcome the high speed spring.

As the engine speed continues to increase, the centrifugal force of the high speed weight increases until this force overcomes the high speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the equalizing lever and the injector control tube levers through the control link lever. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

To stop the engine, the speed control lever is moved to the idle speed position and the solenoid is de-energized or the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in Section 14.3.2.

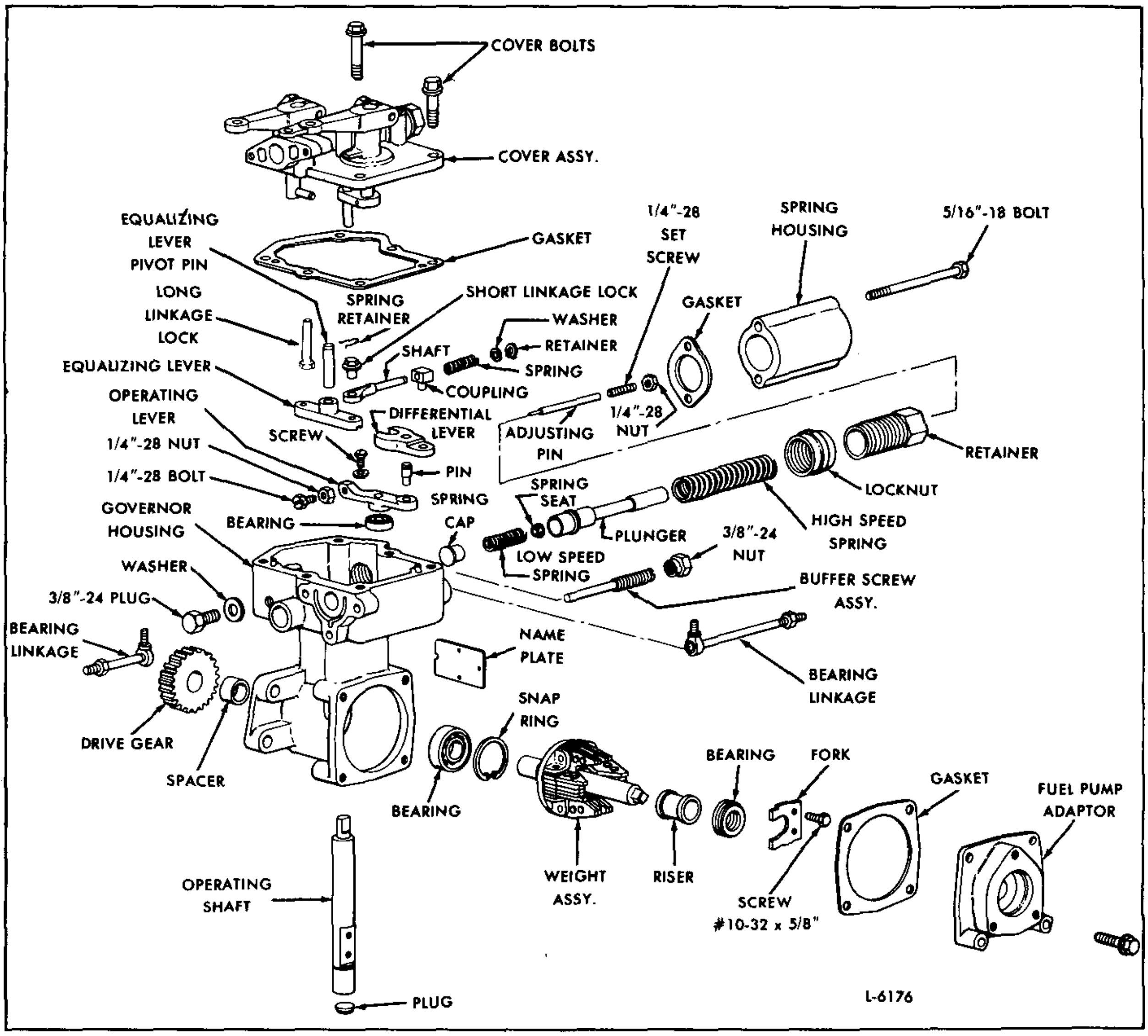


Fig. 2 · Governor Details and Relative Location of Parts

Lubrication

The governor is lubricated by splash lubricating oil, from the gear train in the block, which drains into the governor weight housing. The governor weights sling this oil to various parts of the governor. Excess oil overflows into the gear train compartments and returns to the crankcase.

Remove Governor From Engine

Check the governor and if it fails to control the engine properly, remove and disassemble it for further inspection.

Since the fuel pump is mounted on the governor it will be removed at the same time as the governor assembly.

1. Loosen the hose clamps and slide the hoses back on the fuel rod covers. Disconnect the fuel control rods.

2. Disconnect the linkage to the governor control levers. Also disconnect the fuel lines at the fuel pump.

3. Remove the four governor attaching bolts and remove the governor from the block. Identify and make note of the one shoulder bolt location for proper reassembly.

4. Remove the fuel pump and adaptor then check the clearance between the governor housing wall and each of the fully extended weights. If this clearance is less than 2.0 mm (.080"), the weights or carrier are worn and must be replaced.

> **NOTE:** The weight carrier is hardened in the weight stop areas and the stop area on the high speed weights has been increased with the use of new intermediate laminations to prevent wear which could allow the weights to open beyond limits and strike the governor housing wall.

Disassemble Governor Cover

Disassemble the governor cover (Fig. 3) as follows:

1. loosen the clamping bolt and remove the speed control lever.

2. Remove the retaining ring and two seal retaining washers and withdraw the throttle shaft assembly from the cover.

3. Remove the seal ring from the cover.

4. Loosen the clamping bolt and remove the stop lever.

5. Remove the retaining ring and two seal retaining washers and withdraw the stop lever shaft from the cover.

6. Remove the seal ring from the cover.

7. Wash the governor cover with clean fuel oil and inspect for wear or damage.

Disassemble Governor Springs

Disassemble the governor spring assembly as follows:

1. Remove the low speed spring cap, spring and spring seat from the spring plunger.

2. Depress the high speed spring by hand and remove the idle speed adjusting screw lock nut. The spring retainer and high speed spring may then be withdrawn. Remove the idle speed adjusting screw from the spring plunger.

Disassemble Governor

1. Remove the governor buffer screw and spring.

2. Remove the spring pin and washer from the control link lever pin and withdraw the control link lever and washer.

3. Remove the plug at the bottom of the governor housing.

4. Remove the bearing retaining screw.

5. Remove the screws from the governor operating fork.

6. Remove the operating shaft by placing the inverted governor housing on the bed of an arbor press; use wood block(s) to prevent damage to the dowel pins in the housing. Press on the shaft, using a rod small enough to pass through the housing hole, until it is free.

7. Withdraw the operating shaft, operating shaft lever and bearings.

8. Press the shaft from the operating shaft lever and the upper bearing.

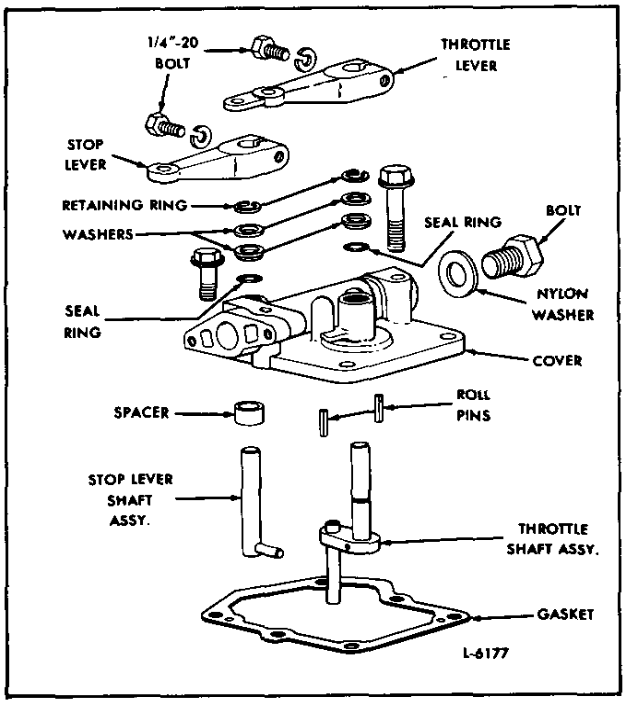


Fig. 3 - Governor Cover Details and Relative Location of Parts

9. Remove the gear and the spacer from the shaft.

10. Remove the governor weight shaft and carrier assembly from the housing by pressing through the bearing.

11. Remove the snap ring, then the weight shaft bearing from the housing.

Disassemble Governor Weights and Shaft

1. Remove the retaining rings from the governor weight pins. Then, drive the pins out by tapping on a punch held against the grooved end of the pins. Remove the governor weights.

2. With the shaft and weight carrier suitably supported on the bed of an arbor press, press the shaft from the governor weight carrier.

3. Slide the governor riser and bearing assembly from the shaft.

4. Tap the governor weight shaft bearing from the shaft. If the bearing is a tight fit use a spacer against the inner race of the bearing, press or tap the bearing from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

Inspect all of the bearings. Replace corroded or pitted bearings. Revolve ball bearings slowly by hand. Replace bearings which indicate rough or tight spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new riser thrust bearing assembly.

Inspect the control link lever, and control link lever pin for wear. Replace worn parts. If a new control link lever pin is required, remove the old pin and press the new pin in.

Examine the weight carrier, weights and pins. Replace worn parts.

Inspect the governor springs, spring seat, spring cap, plunger, spring retainer, adjusting screws and other parts of the governor housing for wear.

Assemble Governor Cover

Assemble the governor cover as follows:

1. Pack the cover hole with grease. Then, slide the throttle shaft assembly through with the fulcrum lever pin seated in the slot on the underside of the cover.

2. Install a new seal ring on top. Then, install the two seal retaining washers and the retaining ring. Make sure the stepped washer is inverted to hold the seal ring in position.

3. Lubricate the stop lever shaft with engine oil. Then slide the shaft through the cover.

4. Install a new seal ring over the shaft. Then, install the two seal retaining washers and the retaining ring. Make sure the stepped washer is inverted to hold the seal ring in position.

5. Install the stop lever and speed control lever, then tighten the clamping bolts.

Assemble Governor Weights and Shaft

Assemble the governor weights and shaft (Fig. 4) as follows:

1. Lubricate the governor weight shaft with clean engine oil and slide the riser assembly over the shaft.

2. Press the shaft into the weight carrier. Minimum press fit should be 3400 N. (764 lbs).

3. Position the low speed weights, identified by the short cam arm, on opposite sides of the weight carrier. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then, drive the knurled end in just enough so the retaining ring can be installed on the pin.

4. Install the high speed weights in a similar manner. The high speed weights are identified by the long cam arm.

5. Install the bearing to the housing with the snap ring.

6. Install weight and shaft, spacer and gear and front pump drive cover.

7. Assemble the governor springs as follows:

   a. Thread the lock nut on the spring retainer.

   b. Thread the idle speed adjusting screw into the spring plunger.

c. Place the high speed spring over the spring plunger.

d. Lubricate the spring and plunger assembly with engine oil. Then, install the spring and plunger assembly in the spring retainer and secure it in place with a lock nut. Approximately 1/4" of the idle speed adjusting screw should extend beyond the lock nut.

e. Lubricate and insert the spring seat, low speed spring, and spring cap in the open end of the spring plunger.

f. Place a new gasket over the spring retainer and thread the retainer and spring assembly into the governor housing. Tighten the lock nut finger-tight until the engine tune-up is performed.

Assemble Governor Housing

Assemble the governor housing as follows:

1. Start the upper operating shaft bearing, number side up, on the end of the shaft. Support the lower end of the shaft on an arbor press. Place a sleeve on the inner race and press the bearing against the shoulder on the shaft.

2. Start the operating shaft lever, with the pivot pin up, on the end of the shaft with the flat on the shaft registering with the flat in the lever bore. Use a sleeve to press the lever tight against the bearing.

3. Insert the lever and shaft assembly through the top of the governor housing.

4. Press the upper operating shaft bearing in place using the outer race to press on.

5. Lubricate the bearings with engine oil.

6. Apply a good quality sealant around the edge of a new expansion plug and tap it in place in the housing.

7. Place the differential lever over the pivot pin in the operating shaft lever.

8. If previously removed, install the gap adjusting screw and lock nut in the tapped hole in the operating shaft lever.

9. Install the equalizing lever with the slotted holes down, over the pin in the governor housing. Secure the lever with the washer and spring pin.

10. Secure the yield link and fuel control rod assemblies to the equalizing lever with special nuts. Torque the special nuts to 4.5-5.0 Nm (40-44 lb-in).

NOTE: Clean the threads on the fuel rod

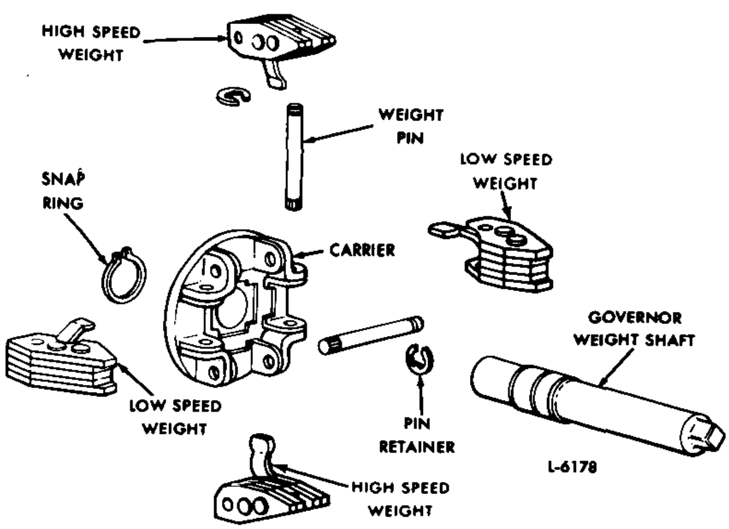


Fig. 4 - Governor Weight Details and Relative Location of Parts

bearing assembly and linkage locks. Apply Loctite 242 to the thread and torque the linkage locks to 4.5-5.0 Nm (40-44 lb-in). Do not allow Loctite to flow into the bearing.

11. Thread the buffer screw into the governor housing until it extends 14 to 16 mm (9/16" to 5/8") beyond the governor housing and install the lock nut.

Install Governor

Install the governor on the engine as follows:

1. Place a new gasket on the governor assembly and attach the housing to the cylinder block with four bolts. One shoulder bolt belongs in the upper right location (facing toward front).

2. Attach the fuel rods to the governor control link lever. Adjust length per Section 14.3.2.

3. Slide the fuel rod cover hoses in place and secure them with the hose clamps.

> **NOTE:** Add 0.5 liter of SAE 30 oil (one pint) before installing the cover.

4. Place a new gasket on the governor housing and install the cover and lever assembly. Make sure the control link lever engages the pin on the differential lever. Also, be sure the pin in the speed control shaft enters the slot in the differential lever and that the pin in the stop lever shaft is engaged between the wall on the housing and the vertical extension of the control link lever. Check the governor gear backlash. It should be 0.0762-0.127 mm (0.003-0.005"). Then, secure the cover with six bolts.

> **NOTE:** The serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position.

5. Install the fuel pump and connect the fuel lines.

6. Connect the linkage to the governor control levers after the engine tune-up is performed.

7. Perform an engine tune-up.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR CALIBRATOR READINGS

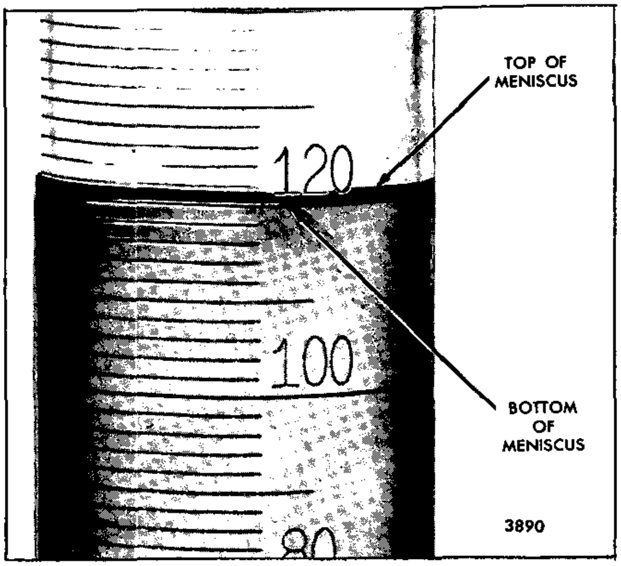


Fig. 1 - Checking Fuel Output

Several factors affect the injector calibrator output readings. The four major items are:

1. **Operator Errors:** If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to Fig. 1.

2. **Air In Lines:** This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

3. **Counter Improperly Set:** The counter should be set to divert the injector output at 1,000 strokes.

This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

4. **Test Oil:** A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in Fig. 2. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2 and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the

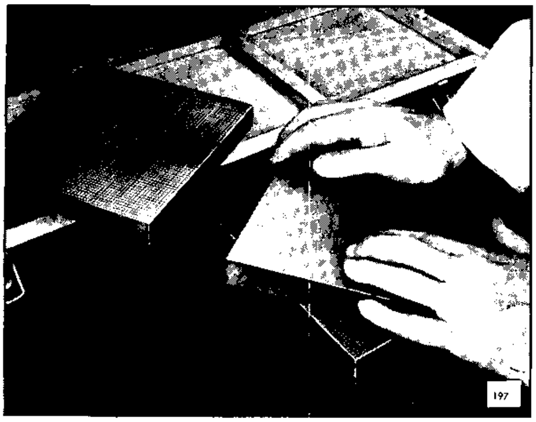


Fig. 2 - Refinishing Lapping Blocks J 22090

powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

EFFECT OF PREIGNITION ON FUEL INJECTOR

Preignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When preignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of preignition to avoid recurrence of the problem. Check for high crankcase pressure, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit (J 26298) to determine the accuracy of the injector calibrator.

With the test fluid temperature at 38°C ±1°(100°F ±1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

FUEL LINES

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

A fuel return restriction orifice is incorporated in the construction of the fuel junction block. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check the filter cover bolts for tightness.

LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

INSTALLATION OF VARIABLE LOW SPEED FEATURE TO LIMITING SPEED GOVERNOR

(Flexible Shaft)

Removing the Current Spring Pack

1. Remove the spring housing (Fig. 4).

2. Loosen the spring retainer locknut.

3. Remove the spring pack by turning the high speed spring retainer counterclockwise. Do not disturb the idle screw. The spring pack parts will usually stay together and can be removed as one unit. Verify that the low speed spring cap was removed with the assembly.

Assemble the New Spring Pack From Components in Kit

1. Thread the locknut on the high speed spring retainer.

2. Place the high speed spring on the retainer.

3. Place the plunger in the high speed spring retainer.

4. Thread the adjusting locknut on the plunger until the plunger protrudes 6.35-9.53 mm (1/4" - 3/8").

5. Thread the low speed adjusting shaft onto the shaft retainer until it bottoms (finger tight).

6. Thread the retainer on the high speed plunger 4-5 threads.

7. Insert the low speed plunger into the high speed plunger.

8. Insert the inner and outer low speed springs into the high speed plunger.

9. Install the low speed spring cap in the end of the high speed plunger.

Installation of the New Spring Pack

1. Install the new spring housing gasket.

2. Install the new spring pack and turn the retainer clockwise until 8-10 threads are engaged.

Set the High Speed Adjustment

1. Install an accurate tachometer.

2. Check for proper operation of fuel shut off.

3. Back out the buffer screw approximately 12.7 mm (1/2").

4. Start and warm up the engine.

5. Check the no-load speed.

6. Adjust the no-load speed to 3200 ± 50 rpm (Rotate the speed retainer clockwise for an increase in rpm).

7. Tighten the locknut on the high speed retainer.

Idle Speed Adjustment

1. Turn the low speed adjusting shaft retainer as required to obtain an idle speed of 700 ± 50 rpm.

2. Tighten the locknut against the adjusting shaft retainer.

3. Recheck idle speed.

4. Adjust the buffer screw to increase the idle speed 5 to 15 rpm.

5. Check the no-load speed, it must be 3250 ± 50 rpm.

Spring Housing Installation

Some engines may require modification of the water outlet elbow. Place the spring housing in position and determine whether the lower bolt can be installed and tightened without interference between the bolt head and water elbow. If not, carefully remove the minimum amount of material necessary from the water elbow at the point of contact.

Install the housing and tighten the bolts.

Install Flexible Shaft Assembly

1. Install the adjusting coupling in the spring housing.

2. Connect the flexible shaft assembly to the spring housing and to the manual control assembly.

Engine idle is now variable. By turning the speed adjusting handle any speed may be selected in a range from normal idle (700 ± 50 rpm) to approximately 1750 rpm.

CAUTION: Return engine to normal idle speed before attempting vehicle operation.

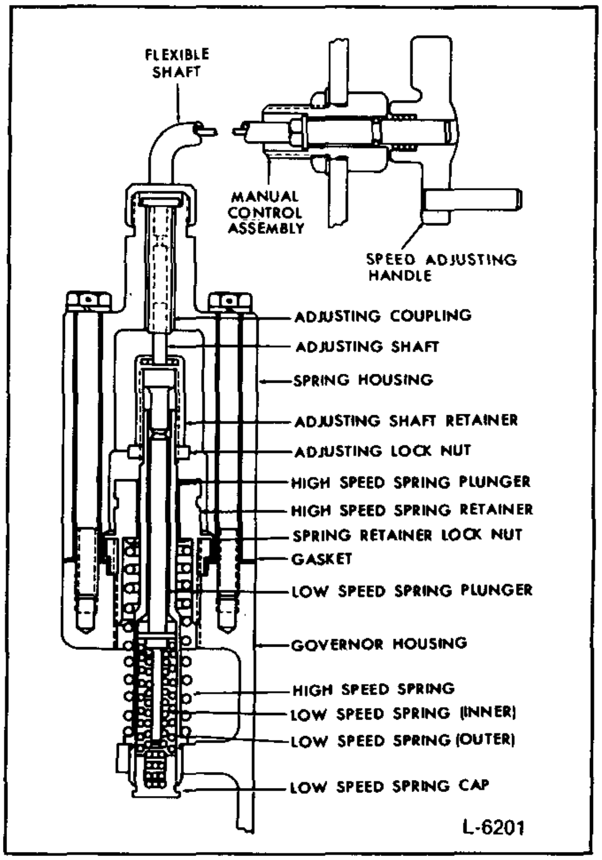


Fig. 4 - Limiting Speed Governor with Variable Low Speed Feature

INSTALLATION OF VARIABLE LOW SPEED FEATURE TO LIMITING SPEED GOVERNOR

(Air Operated)

Removing the Current Spring Pack

1. Remove the current spring housing (Fig. 5).

2. Loosen the spring retainer lock nut.

3. Remove the spring pack by turning the high speed spring retainer counterclockwise. Do not disturb the idle screw. The spring pack parts will usually stay together and can be removed as one unit. Verify that the low speed cap was removed with the assembly.

Assemble the New Spring Pack From Components in Kit

1. Thread the lock nut on the high speed spring retainer.

2. Place the high speed spring on the retainer.

3. Place the plunger in the high speed spring retainer.

4. Thread the high speed jam nut on the plunger (high speed plunger should protrude 6.35 mm (1/4").

5. Thread the cylinder assembly on the high speed plunger 4 - 5 threads.

6. Insert the low speed plunger into the high speed plunger.

7. Insert the inner and outer low speed rings into the high speed plunger.

8. Install the low speed spring cap in the end of the high speed plunger.

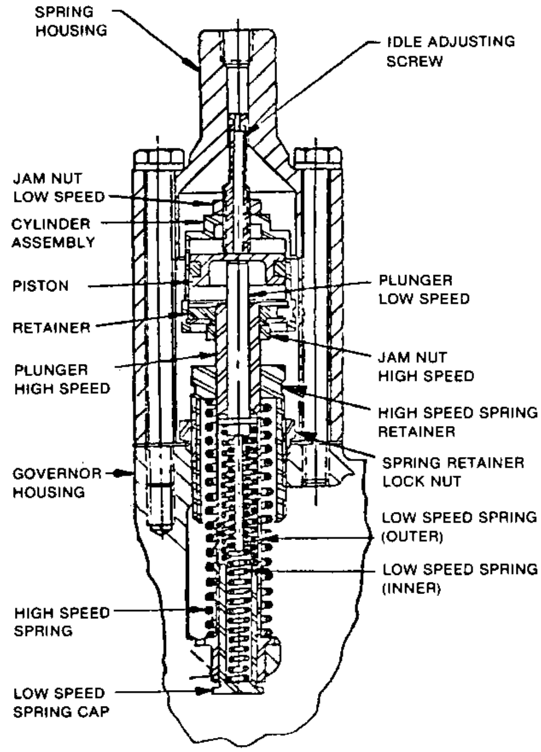


Fig. 5 - Limiting Speed Governor with Air Operated Variable Low Speed Feature

Installation of the New Spring Pack

1. Install the new spring housing gasket.

2. Install the new spring pack and turn the retainer clockwise until 8-10 threads are engaged.

Set the High Speed Adjustment

1. Install an accurate tachometer.

2. Check for proper operation of the fuel shut off.

3. Back out the buffer screw approximately 12.7 mm (1/2").

4. Start and warm up the engine.

5. Check the no-load speed.

6. Adjust the no-load speed of 3200 ± 50 rpm (Rotate the high speed retainer clockwise to increase rpm).

7. Tighten the lock nut on the high speed retainer.

Set Maximum Idle Speed Adjustment

1. Turn the idle adjusting screw clockwise into the cylinder assembly until the piston contacts the retainer. The cylinder assembly should be 2-3 threads from its position of maximum engagement with the high speed spring plunger to prevent the piston from contacting the high speed spring plunger before it contacts the retainer.

NOTE: Do not force the idle adjusting screw.

2. Start the engine and with the throttle in the idle position, rotate the cylinder clockwise to increase the idle speed.

Set Minimum Idle Speed Adjustment

Make this adjustment after the maximum idle speed adjustment is completed.

1. With the engine operating with the throttle in the idle position, turn the idle adjusting screw counter-clockwise to lower the idle speed and clockwise to raise the idle speed as required to obtain an idle speed of 700 ± 50 rpm.

2. Lock the idle screw in the position which provides the desired engine idle speed with the low speed jam nut.

3. Recheck the idle speed.

4. Adjust the buffer screw to raise the idle speed 5-15 rpm.

5. Check the no-load speed. It must be 3250 ± 50 rpm.

6. Stop the engine.

7. Lubricate the bore of the spring housing with engine oil.

Install Spring Housing

Some engines may require modification of the water outlet elbow. Place the spring housing in position and determine whether the lower bolt can be installed and tightened without interference between the bolt head and water elbow. If not, carefully remove the minimal amount of material necessary from the water elbow at the point of contact.

Install the housing and tighten the bolts.

CAUTION: Return the engine to normal (idle speed before attempting vehicle operation).

INSTALLATION INSTRUCTIONS FOR THE ADDITION OF AN AIR OPERATED DUAL HIGH SPEED FEATURE TO LIMITING SPEED GOVERNOR

Removing the Current Spring Pack

1. Remove the spring housing (Fig. 6).

2. Loosen the spring retainer locknut.

3. Remove the spring pack by turning the high speed spring retainer counterclockwise. Do not disturb the idle screw and all the spring pack parts will stay together and can usually be removed as one unit. Check to verify that the low speed spring cap was removed with the assembly.

Assemble the New Spring Pack from Components in Kit

1. Position the high speed spring, spring seat and high speed spring retainer on high speed plunger and secure with idle speed adjusting screw and locknut.

2. Insert low speed spring seat, low speed spring and spring cap in high speed plunger.

3. Position new gasket on governor housing with holes in gasket aligned with holes in housing and install high speed spring retainer with parts assembled in steps 1 and 2 above in governor housing.

4. Install seal ring in groove in piston.

5. Lubricate inside surface of spring housing with grease and install piston in the end of housing opposite the threaded boss.

6. Install the five 1.366 mm (0.0538") shims and five 0.254 mm (0.010") shims in recess of piston.

7. Install the high speed spring guide on top of the shims and piston.

8. Install the spring housing with the piston, shims and guide over the high speed retainer so the guide is riding on the high speed spring seat.

9. Install the new gasket and cover on the spring housing to the governor housing with two lock washers and bolts.

> **NOTE:** Early engines require a new right bank water outlet elbow to allow clearance for housing installation.

10. Install the copper washer, low maximum speed adjusting screw and locknut in cover.

High Maximum No Load Speed Adjustment

1. Install an accurate tachometer.

2. Check the operation of the fuel shutoff.

3. Back out the buffer screw until it extends 15.875 mm (5/8") from the surface of the governor housing.

4. Start and run the engine until normal operating temperatures are reached (refer to Section 13.2).

5. With the engine at operating temperature and no load on the engine, position the throttle control lever in maximum throttle position.

6. Apply 621 kPa (90 psi) minimum air pressure to the inlet in the governor spring housing and note engine speed. The no-load speed should be 3200± 50 rpm. If any other reading is noted, stop the engine and remove the spring housing. Remove the spacer and piston from the spring housing and add 0.254 mm (0.010″) shims to raise engine rpm, or remove 0.254 mm (0.010″) shims to decrease engine rpm (each shim, added or removed, will increase or decrease engine speed approximately 10 rpm). Reinstall piston and spacer spring housing. Position spring housing back on governor. Repeat steps 4 through 6 above until 3200± 50 rpm is obtained.

Idle Speed Adjustment

1. Remove high speed spring retainer cover, piston and guide as an assembly.

2. With the engine operating with the throttle in the idle position, turn the idle adjusting screw counterclockwise to lower idle speed and clockwise to raise idle speed as required to obtain an idle speed of 700 ± 50 rpm.

3. Lock idle screw in the position which provides the desired engine idle speed with the low speed jam nut.

4. Recheck idle speed.

5. Adjust buffer screw to raise idle speed 5 to 15 rpm.

6. Reinstall items removed in Step 1.

7. Apply air pressure and check no-load speed. It should be 3250± 50 rpm.

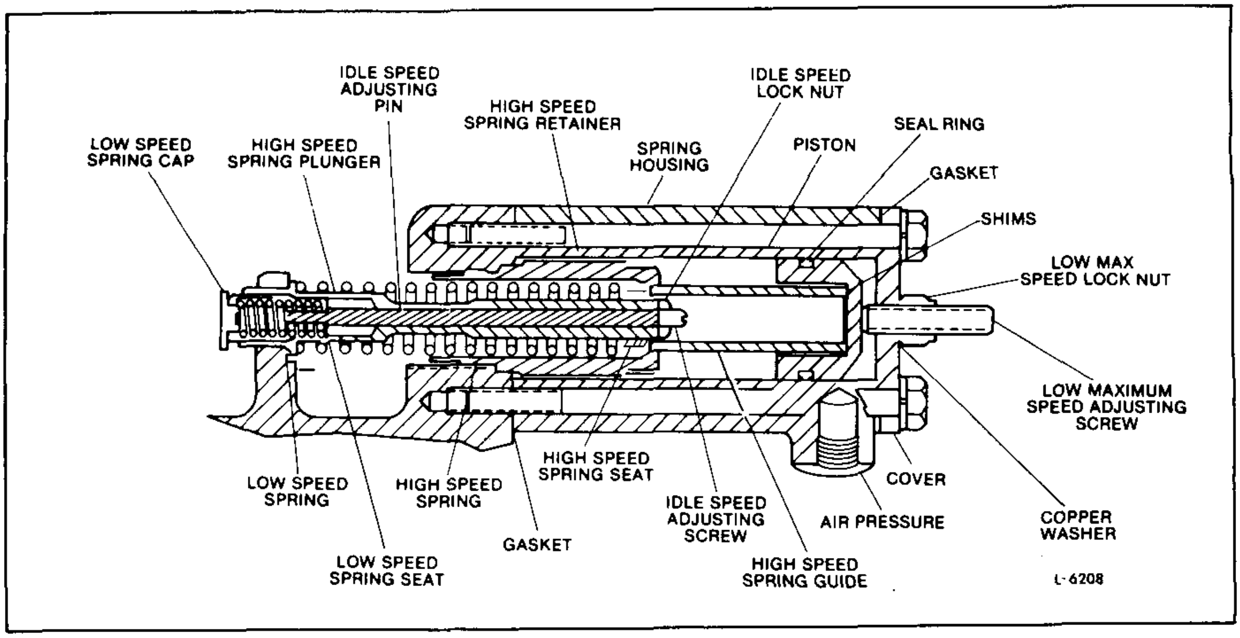


Fig. 6 - Limiting Speed Governor Dual High Speed Feature.

Low Maximum No-Load Speed Adjustment

1. With engine at operating temperature, no load on lthe engine and no air pressure at the governor spring housing place throttle control lever in maximum throttle position.

2. Loosen locknut, and turn low maximum speed adjusting screw in to increase or out to decrease engine speed, until desired low maximum speed is obtained (minimum available 2000 rpm).

3. Hold adjusting screw and tighten locknut.

TROUBLE SHOOTING

FUEL PUMP

The fuel pump is so constructed as to be inherently trouble free. By using clean, water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

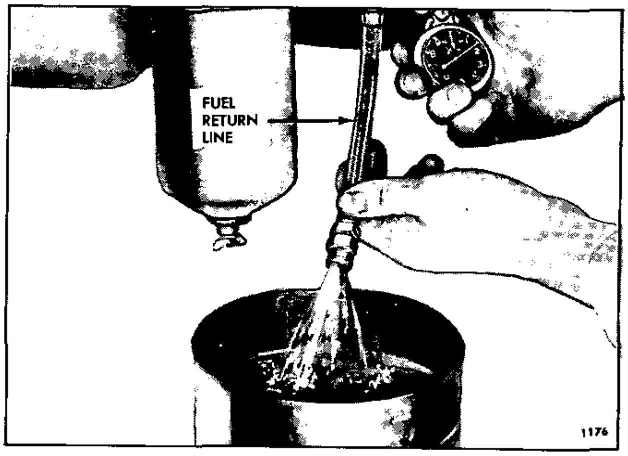


Fig. 4 - Measuring Fuel Flow

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 4).

2. Start and run the engine at maximum no load and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.

3. Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

4. If the fuel flow is insufficient for satisfactory engine performance, then:

a. Replace the element in the fuel strainer. Then start the engine and run it at maximum no load to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below:

b. Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in Step "c".

c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

TROUBLE SHOOTING CHARTS

Chart 1

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Cause

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN SPRAY TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
4. WORN OR BROKEN VALVE SPRING
5. DIRT OR FOREIGN MATERIAL IN INJECTOR

HIGH VALVE OPENING PRESSURE

Probable Cause

6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
7. CARBON IN SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the needle valve and spray tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean all of the parts.
6. Remove the carbon in the spray tip with tip reamer J 9464-01 which is especially designed and ground for this purpose.
7. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

Chart 2

INJECTOR FAILS EXTERNAL LEAK TEST AND PRESSURE HOLDING TEST

Probable Cause

1. POOR BUSHING TO BODY FIT
2. INJECTOR NUT NOT TIGHTENED TO SPECIFIED TORQUE
3. EXCESSIVE PLUNGER TO BUSHING CLEARANCE. PLUNGER SCRATCHED
4. CRACKED SPRAY TIP
5. WORN OR ERODED NEEDLE VALVE
6. WORN OR ERODED NEEDLE VALVE SEAT IN SPRAY TIP
7. WORN OR BROKEN NEEDLE VALVE QUILL
8. WORN OR BROKEN VALVE SPRING
9. WORN OR DAMAGED VALVE SPRING SEAT
10. DEFECTIVE SEAL RINGS, BODY AND NUT
11. SPRAY TIP TO NUT SEAT LEAKING (ERODED OR DAMAGED)

SUGGESTED REMEDY

1. Lap the injector body. Inspect shelf of bushing.

2. Tighten the injector nut to 95-108 Nm (70-80 lb-ft). torque. Do not exceed the specified torque.

3. Replace the plunger and bushing.

4, 5, 6 and 7. Replace the needle valve and spray tip assembly.

8. Replace the valve spring.

9. Replace the valve spring seat.

10. Replace the damaged seal rings.

11. Replace tip. Resurface nut or replace.

Chart 3

INCORRECT INJECTOR OUTPUT

Probable Cause

1. SPRAY TIP OR ORIFICES PARTIALLY PLUGGED
2. SPRAY TIP ORIFICES ENLARGED
3. CARBON BUILD-UP IN SPRAY TIP
4. WORN PLUNGER AND BUSHING
5. WORN OR DAMAGED NEEDLE VALVE QUILL
6. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
7. WORN OR BROKEN VALVE SPRING
8. CRACKED CHECK VALVE CAGE, SPRING CAGE OR SPRAY TIP
9. CRACKED BUSHING
10. IMPROPERLY LAPPED SURFACES
11. FOREIGN MATERIAL BETWEEN VALVE AND SEAT
12. RACK AND GEAR NOT IN TIME
13. SPRAY TIP-PLUNGER AND BUSHING COMBINATION PROVIDES INCORRECT OUTPUT

SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts*.

2. Replace the needle valve and spray tip assembly.

3. Clean the spray tip with tool J 1243.

4. After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

   NOTE: The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits try changing the spray tip. However, use only a tip specified for the injector being tested.

5. Replace the needle valve and spray tip assembly.

6. Replace the spring seat.

7. Replace the valve spring.

8. Replace the cracked parts.

9. Replace the plunger and bushing assembly.

10. Lap the sealing surfaces.

11. Disassemble the injector and clean all of the parts.

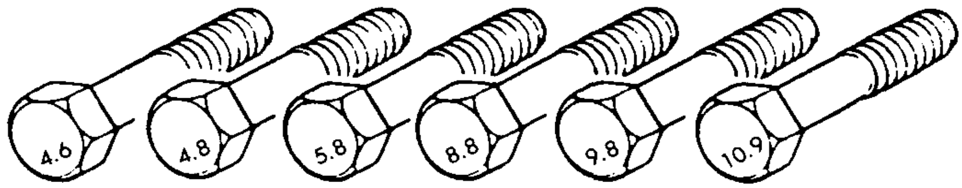
12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.

13. Replace the spray tip and the plunger and bushing assembly to provide the correct output.

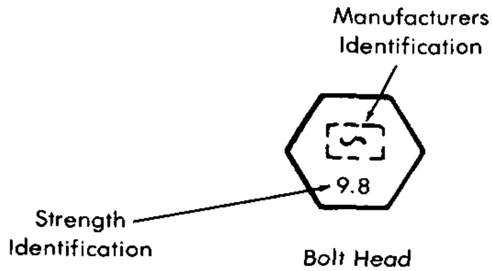
STANDARD METRIC BOLT AND NUT TORQUE SPECIFICATIONS

Thread Size Diameter × MM Per Thread	BOLT CLASSES / TORQUES		
	8.8	**9.8**	**10.9**
	Nm/LB-FT	Nm/LB-FT	Nm/LB-FT
M5 × .8	None used	5.0-6.0/3.7-4.4	7.0-8.0/5.2-5.9
M6 × 1.0	" "	10-12/7.4-9.0	13-15/10-11
M8 × 1.25	" "	23-27/17-20	30-34/22-25
M10 × 1.50	" "	46-53/34-39	58-66/43-49
M12 × 1.75	" "	79-91/58-67	101-116/74-86
M14 × 2.0	" "	126-144/93-106	160-184/118-136
M16 × 2.0	" "	192-220/142-162	245-280/181-207
M20 × 2.5	334-384/246-283	None used	478-550/353-406

STANDARD METRIC BOLTS



Metric Bolts — Identification class numbers correspond to bolt strength — Increasing numbers represent increasing strength.



BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (Nm)	TORQUE (lb-ft)
Injector clamp bolt	M6 x 1.0 x 30	10-12	7-9
Fuel pump bolt	M8 x 1.25 x 25	23-27	17-20
Injector control shaft lever bolt	M8 x 1.25 x 20	30-34	22-25
Fuel filter mounting bracket bolt	M10 x 1.50 x 25	46-53	34-39
Fuel junction block bolt	M10 x 1.50 x 80	46-53	34-39
Governor mounting bolt	M10 x 1.50 x 30	46-53	34-39

SERVICE TOOLS

TOOL NAME	TOOL NO.
Fuel Injector	
Carbon remover tool	J 29575
Lapping blocks	J 22090
Injector auxiliary tester	J 22640
Injector calibrator	J 22410
Injector follower bolding fixture	J 29136
Injector nut wrench	J 29137
Injector spray tip cleaning tool	J 24838
Injector test oil	J 26400
Pop-n-Fixture	J 29531
Rack freeness tester	J 29584
Spring tester	J 22738-2
Wire buffing wheel	J 7944
Fuel Injector Tube	
Injector tube service tool set	J 29124
Pilot tube tip refinisher	J 5286-8
Fuel Pump	
Adaptor	J 1508-10
Holding fixture	J 1508-10
Oil seal installer handle	J 1508-8
Oil seal remover	J 1508-13
Fuel Filter	
Fuel/oil filter wrench	J 22775

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

In the 8.2L engines, air is drawn into the cylinders and thoroughly sweeps out all of the burned gases through the exhaust valve ports (Fig. 1). This air also helps to cool the internal engine parts, particularly the valves. At the beginning of the compression stroke, each cylinder is filled with fresh clean air which provides for efficient combustion.

On some engines a turbocharger is introduced in the air system as illustrated in Fig. 2. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas. The expanding exhaust gases turn a single stage turbo wheel which drives an impeller thus supplying air under pressure to the cylinders.

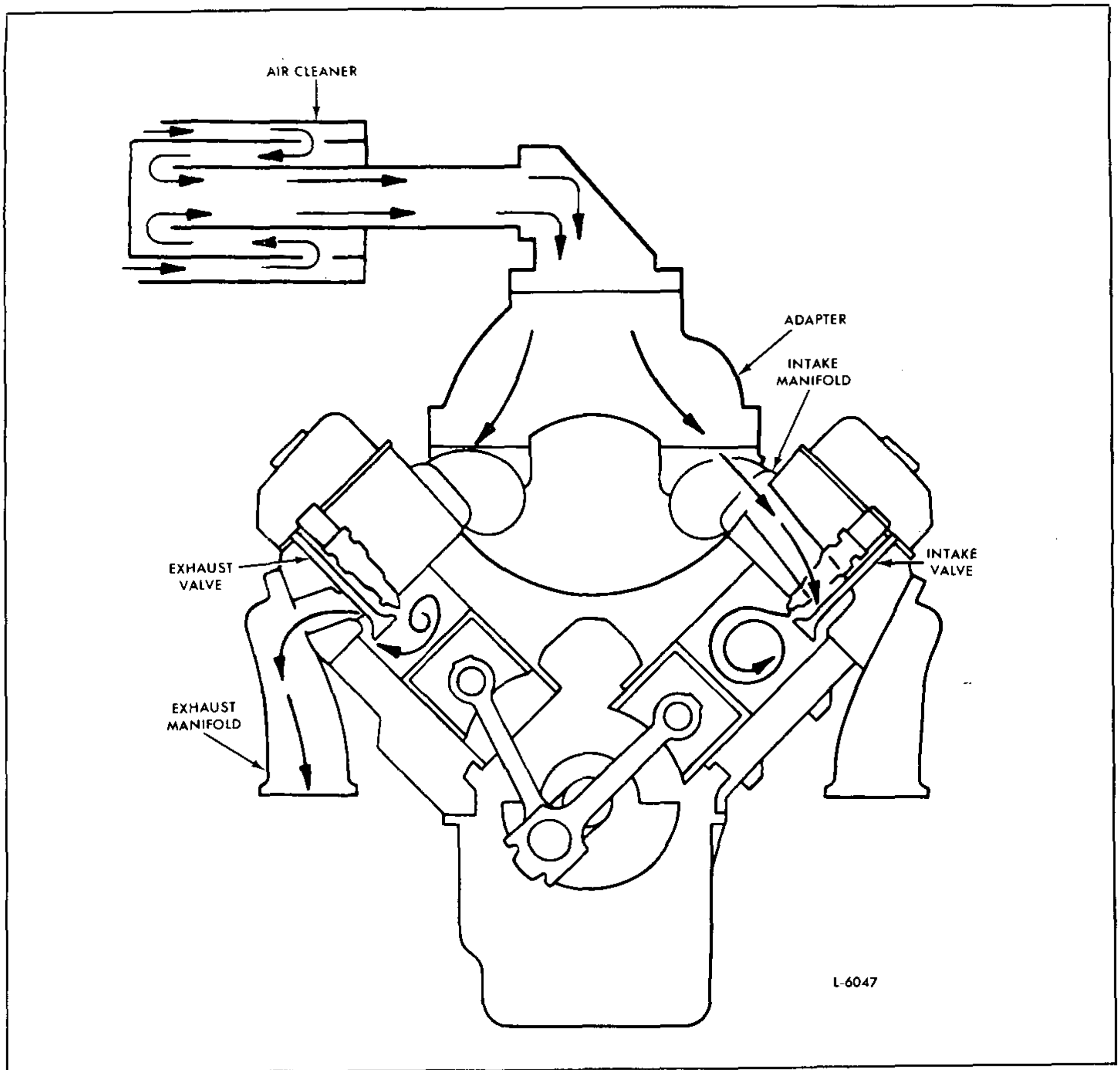


Fig. 1 - Air Inlet System Diagram for N.A. Engine

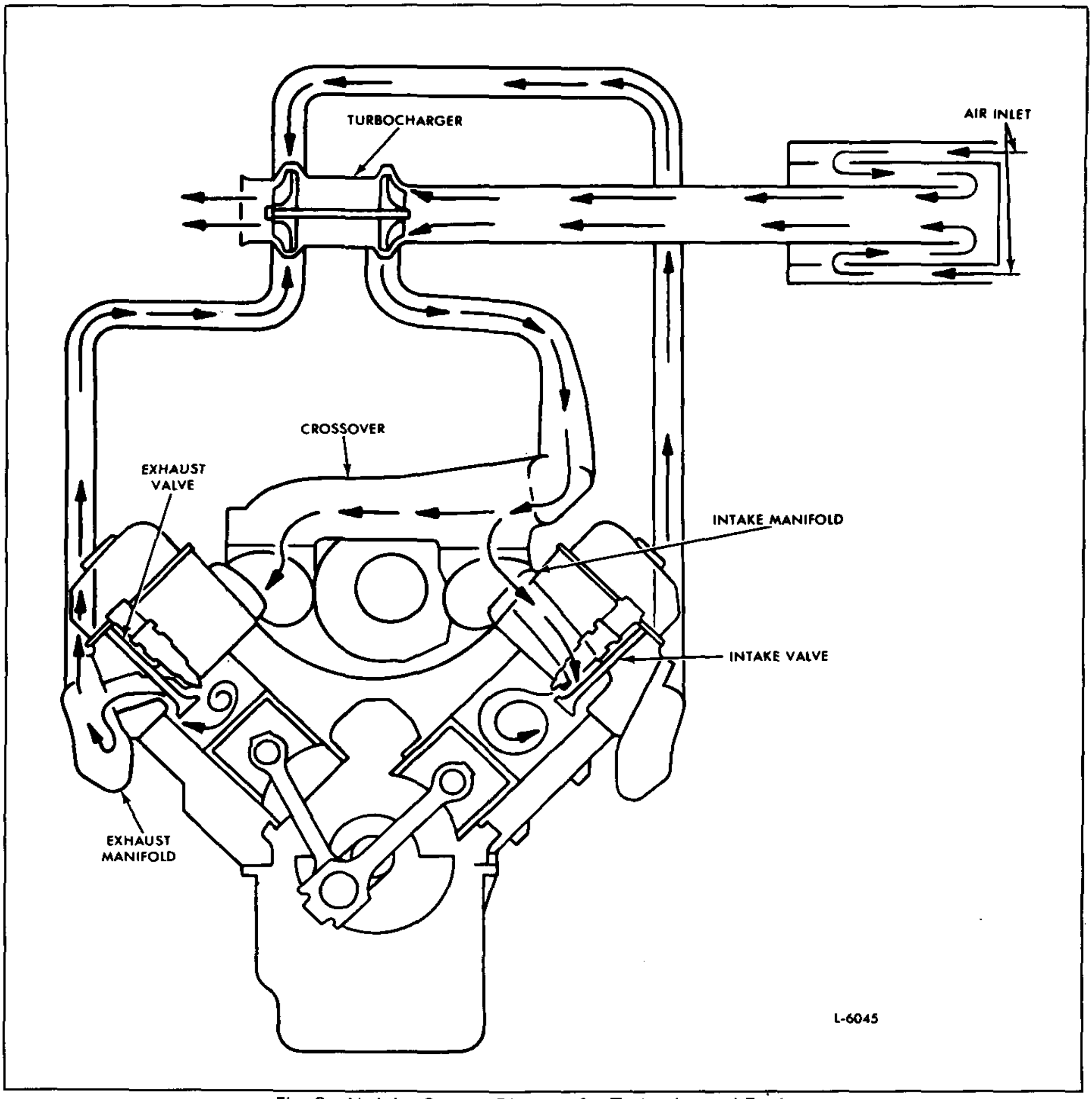


Fig. 2 - Air Inlet System Diagram for Turbocharged Engine

AIR CLEANER

The air cleaner is designed to remove foreign matter from the air, pass the required volume of air for proper combustion and scavenging and maintain efficient operation for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of the engine cannot be over-emphasized, since clean air is so essential to satisfactory engine operation and long engine life. Should dust in the air supply enter the engine it would be carried into the cylinders and due to its abrasive properties, cause premature wear of the moving parts. Dirt, which is allowed to build-up in the air cleaner passages, will eventually restrict the air supply to the engine and result in heavy carbon deposits on the valves and pistons due to incomplete combustion. The air cleaner must have a capacity large enough to retain the material separated from the air to permit operation for a reasonable length of time before cleaning is required.

Air Cleaner Maintenance

Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the duct work, which permit dust-laden air to completely by-pass the the cleaner and enter the engine will lower the efficiency of the air cleaner. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

Servicing an air cleaner depends upon the air supply. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by frequently inspecting the air cleaner under normal operating conditions, then setting the service period to best suit the requirements of the particular engine.

The following maintenance procedure will assure efficient air cleaner operation.

1. Keep the air cleaner tight on the air intake pipe.

2. Keep the air cleaner properly assembled so the joints are strictly air tight.

3. Repair any damage to the air cleaner or related parts immediately.

4. Inspect and clean or replace the air cleaner element as operating conditions warrant. It is possible to clean and reuse the element several times as long as the paper is not ruptured in the process.

5. Carefully inspect the entire system periodically. Enough dust-laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

AIR SILENCER (TURBOCHARGER)

The air silencer used on the air inlet side of the turbocharger absorbs the sound of the incoming air. Air is drawn into a passage formed between the inner and outer covers of the silencer, and flows into the turbocharger compressor. A perforated steel screen that surrounds the silencer prevents any large objects from entering the silencer. The air silencer (Fig. 1) is attached at the air inlet side of the turbocharger with a hose and clamps and is supported by a bolt, spacer and nut attached to the lifter bracket and air silencer.

Service

Very little service, other than an occasional cleaning of the silencer, is required. However, the silencer must be removed when service operations are performed on the turbocharger. Remove the silencer as follows:

1. Loosen retaining clamps and slide out silencer with hose.
2. Remove bolt, nut, bracket and spacer.

Install Air Silencer

1. Install bracket, bolt, spacer and nut. Leave loose.
2. Slide silencer with hose into place and tighten clamps.
3. Tighten bracket bolt and nut. Torque nut to 30-34 N·m (22-25 lb-ft).

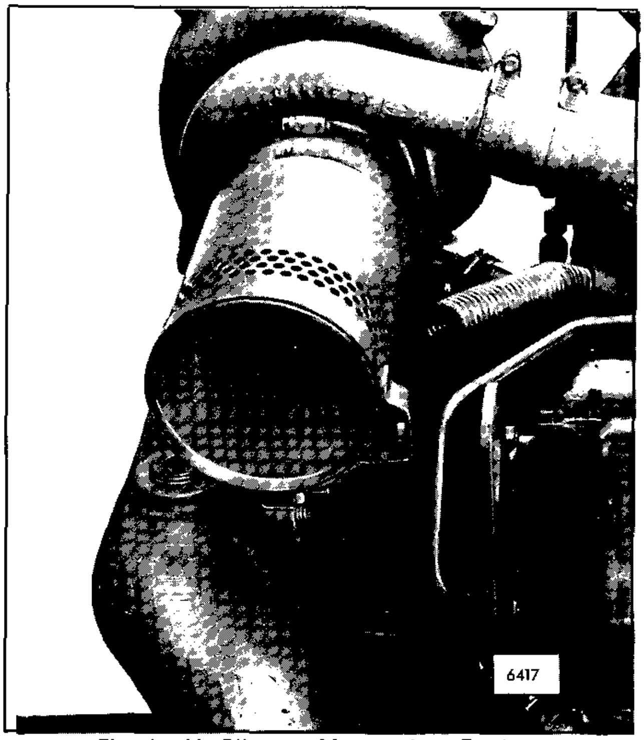


Fig. 1 - Air Silencer Mounted on Engine

MARINE TURBOCHARGER (AIRESEARCH)

The turbocharger (Model TW4103) - (Fig. 1) is designed to increase engine efficiency and power output. Energy to drive the turbocharger is obtained from the engine exhaust gases. Water cooled turbine housing and exhaust outlet piping are utilized to reduce the exhaust temperatures and engine compartment ambient temperatures.

The turbocharger assembly consists of a turbine housing, turbine wheel and shaft assembly, compressor housing, compressor wheel and a center housing assembly.

The turbine housing is fresh water cooled and contains the turbine wheel which is friction welded to the turbine shaft. The turbine housing is bolted to the turbine side of the center housing assembly. The compressor housing contains the compressor wheel which is attached to the threaded end of the turbine shaft by a retaining nut. The compressor housing is bolted to the backplate assemby which is bolted to the center housing assembly. The center housing assembly consists of the center section, bearings, snap rings, thrust collar and thrust bearing. The center housing bearings are pressure lubricated by internal oil passages.

Operation

After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 2). After passing through the turbine housing, the exhaust gases pass into the exhaust elbow where the gases are mixed with raw water before being discharged (Fig. 3).

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft assembly, rotates with the turbine wheel. The compressor wheel draws the ambient air into the compressor housing, compresses the air and delivers it to the engine.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the power output of the engine increases, the flow of exhaust gases increases and the speed and output of the rotating assembly increases proportionately, delivering more air to the engine.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through a special U.S. Coast Guard approved external oil line from the engine to the center housing. The oil flows from the oil inlet in the center housing through the drilled oil passages in the housing to the shaft bearings, thrust collar and thrust bearing (Fig. 4). The oil returns by gravity to the engine oil pan through an external oil tube from the bottom of the turbocharger center housing to the cylinder block.

Periodic Inspection

CAUTION: A turbocharger compressor inlet shield can be fabricated (Fig. 5) and must be used anytime the engine is operated with the air inlet silencer removed. The shield prevents a serviceman from touching the moving impeller and helps to prevent foreign objects entering the turbocharger. The use of

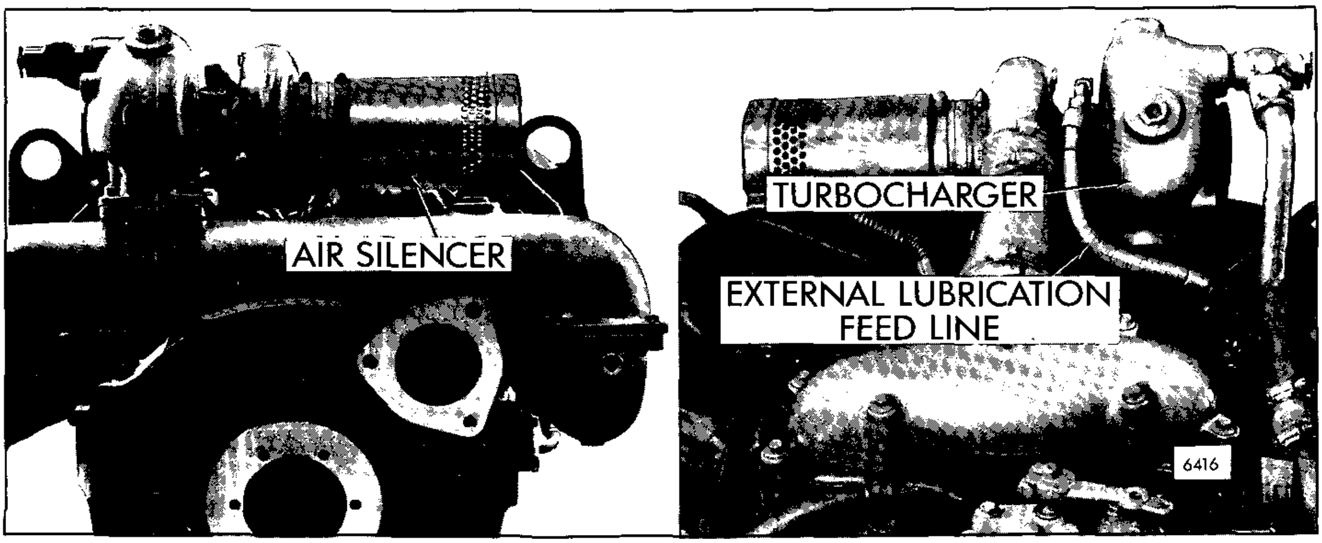


Fig. 1 - Turbocharger Mounting

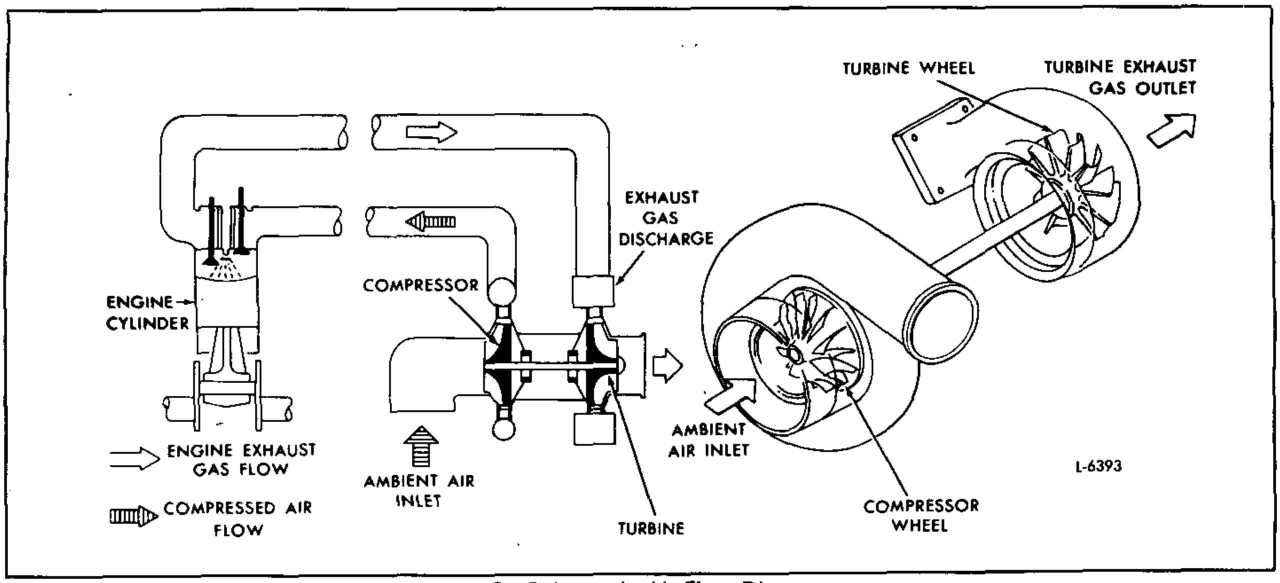


Fig. 2 - Schematic Air Flow Diagram

this shield *does not* preclude any other safety practices contained in this manual.

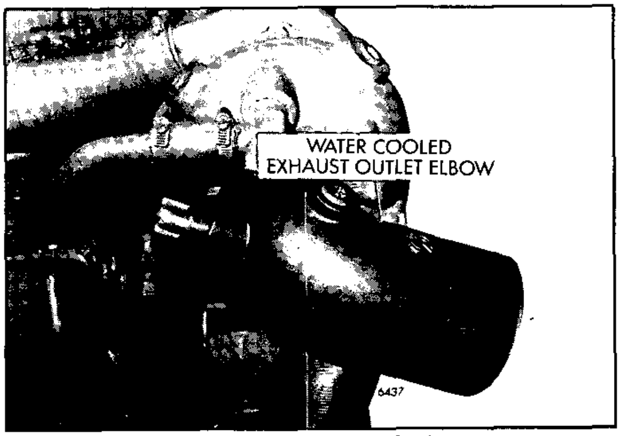


Fig. 3 - Raw Water Exhaust Outlet Elbow

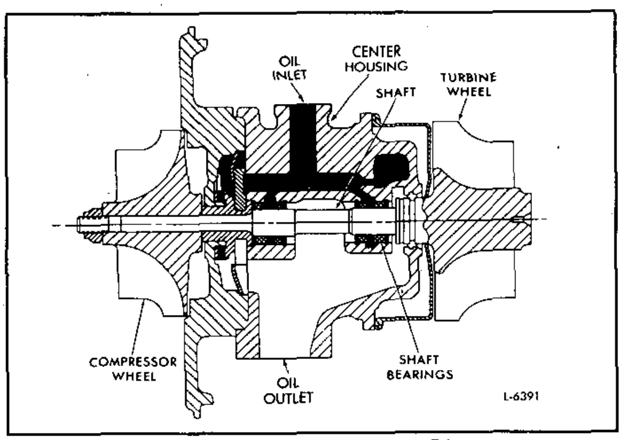


Fig. 4 - Turbocharger Oil Flow Diagram

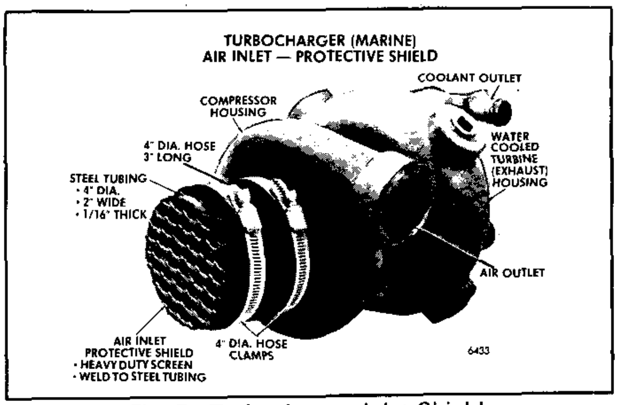


Fig. 5 - Turbocharger Inlet Shield

Excessive restrictions to the air and the exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits. Refer to Section 13.2.

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connections, the turbine inlet and exhaust manifold gasket.

While the engine is stopped remove the air inlet silencer from the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air inlet system. Remove all such accumulations and determine and

correct the cause. Refer to the Troubleshooting Charts in Section 3.0. Uneven deposits left on the compressor wheel can affect the balance and cause premature failure. For proper operation, the turbocharger rotating assembly must turn free.

NOTICE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine.

CHECKING FOR INTERNAL OIL LEAKS

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the air inlet and exhaust outlet restrictions at normal, oil in these sections should disappear. If the oil does not disappear, refer to Section 3.0

Normally the following conditions will contribute to internal leakage of turbocharger shaft oil seals:

1. Worn or damaged oil seals.
2. High air inlet restriction due to air silencer inlet problems or insufficient engine compartment air supply.
3. Restricted turbocharger oil return line.

The following steps are recommended to troubleshoot and diagnose suspected oil leakage:

Step 1 - First, determine if the oil return line is not plugged, bent or restricted.

Step 2 - Next, determine that the air inlet restriction or engine compartment air supply is within Detroit Diesel operating limits. Refer to Section 13.2.

If step 1 or step 2 do not reveal any problem then proceed with step 3.

Step 3 - If compressor housing oil seal leaking is still suspected, the following procedure should be used:

a. Remove the compressor housing from the turbocharger.
b. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the compressor backplate annulus with suitable solvent spray and then dry completely with shop air.
c. Spray the backplate annulus with a light coating of Magna-Flux Spot-Check developer type SKD-MF or equivalent.
d. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.
e. Warm-up the engine to normal operating temperature.
f. Operate the engine at no load at the governor limited high speed for approximately five minutes.
g. Return the engine to low idle and then stop it.
h. Remove the air intake silencer and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the Spot-Check developer on the backplate annulus. This surface should be completely free of oil streaks after the test.
i. If leakage is detected and oil is positively not entering through the air silencer, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Make certain the raw water supply is shut off.
2. Drain the engine cooling system.
3. Remove the air silencer, clamps and retainers. Refer to Section 3.2.
4. Remove the turbocharger coolant return tube, clamps and hose.
5. Remove the oil supply line from the turbocharger center housing.
6. Remove the oil drain tube, bolts, clamps and hose from the turbocharger.
7. Remove the clamps and slide the hose out of position from the air intake.
8. Remove the marmon clamp at the turbine exhaust outlet.
9. Disconnect the raw water connection at the exhaust outlet elbow and remove the elbow or slide out of position.
10. Remove the flange mounting nuts and remove the turbocharger assembly.
11. Cover the air inlet, oil holes and exhaust openings on the engine to prevent the entry of foreign material.

NOTICE: Plug and make the exhaust piping water tight to eliminate outside water entry into the engine compartment.

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembling and proceed as follows:

NOTICE: Matchmark the major positions of the compressor housing, backplate assembly, center housing and turbine housing with a center punch or scribe prior to disassembly to assure reassembly in the same relative position. Port and starboard turbocharger assemblies are the same, with the major differences being how they are attached to

the engine cross-over manifold and the directions the inlet and outlet openings are positioned.

1. Refer to Fig. 6 and remove the bolts and clamps securing the compressor and turbine housings to the center section.

   NOTICE: Use care when removing the compressor and turbine housing to prevent damage to the compressor and turbine wheels. Tap the housing with a plastic shot filled hammer if a shocking force is required.

2. Position the turbine wheel of the center housing assembly into a suitable holding fixture J 29086-3 (Fig. 7). Remove the compressor wheel locking nut with a double universal socket and tee-handle.

   NOTICE: To prevent the possibility of bending the turbine shaft use the above tool combination.

3. Lift the compressor wheel off the turbine wheel shaft assembly (Fig. 8).
4. Invert the center housing and turbine wheel assembly and pull out from the center section the turbine wheel assembly (with piston seal ring). Remove and discard the piston seal ring from the turbine shaft (Fig. 9).
5. Remove the wheel shroud.
6. Bend the lock tabs down with a hammer and drift and remove the bolts and lock tabs that secure the

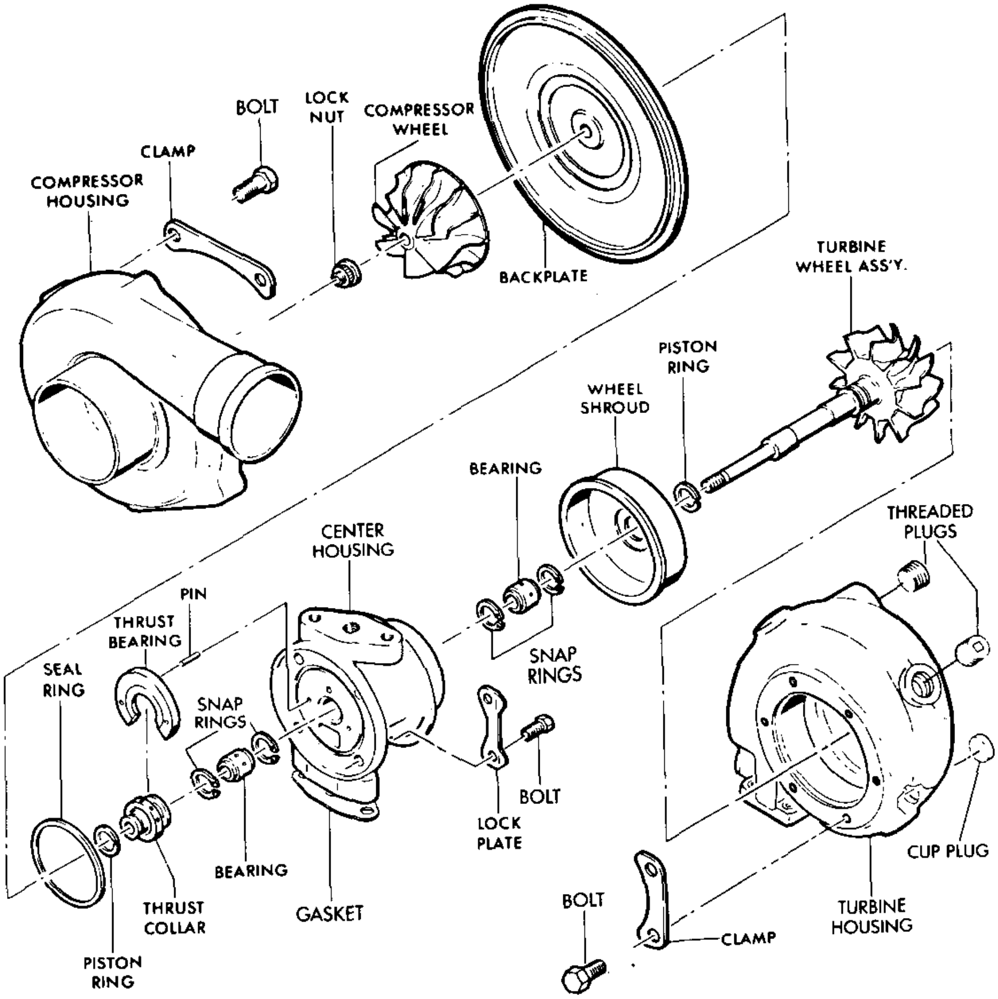


Fig. 6 - Model TW4103 Turbocharger and Relative Location of Parts

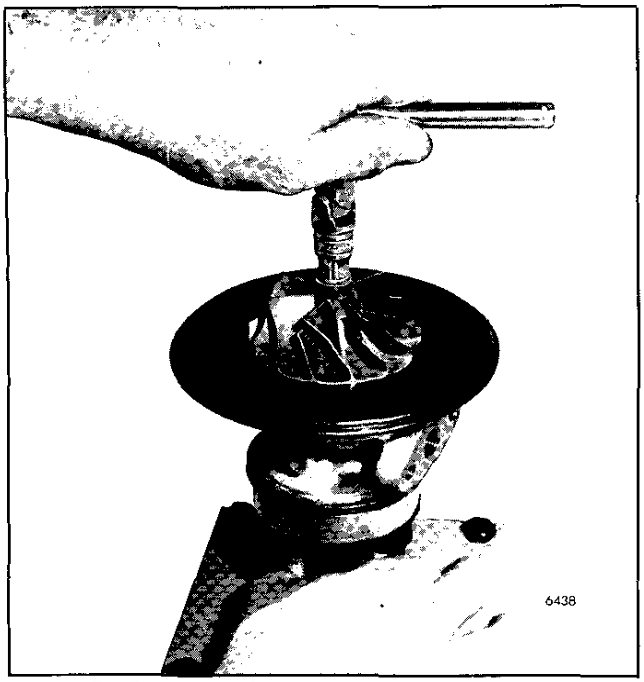


Fig. 7 - Removing Compressor Wheel Locking Nut

compressor backplate assembly to the center section. Remove the backplate assembly (Fig. 10).

NOTICE: Tap the backplate lightly to remove it from the center housing recess.

7. Remove and discard the seal ring from the groove in the center housing (Fig. 11).
8. Lift the thrust bearing and thrust collar from the center section and remove and discard the piston seal ring (Fig. 12).
9. Remove the outer snap ring using J 28507, bearing and inner snap ring from the compressor side of the center section (Fig. 13).

Fig. 8 - Removing Compressor Wheel From Turbine Shaft

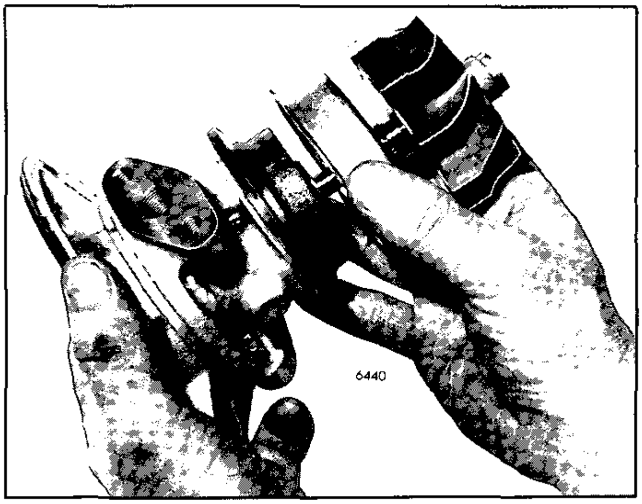


Fig. 9 - Removing Turbine Shaft Assembly from Center Housing

10. Remove the outer snap ring using J 28507, bearing and inner snap ring from the turbine side of the center section.

Cleaning

Before cleaning, inspect all of the parts for signs of rubbing, burning or other damage which might not be evident after cleaning.

If for any reason the engine coolant system requires cleaning refer to Section 5 of this service manual for recommended procedures.

Soak all parts except for the turbine housing in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle brush and remove all dirt particles. Dry all the parts thoroughly.

CAUTION: Never use a caustic cleaning solution for cleaning as this

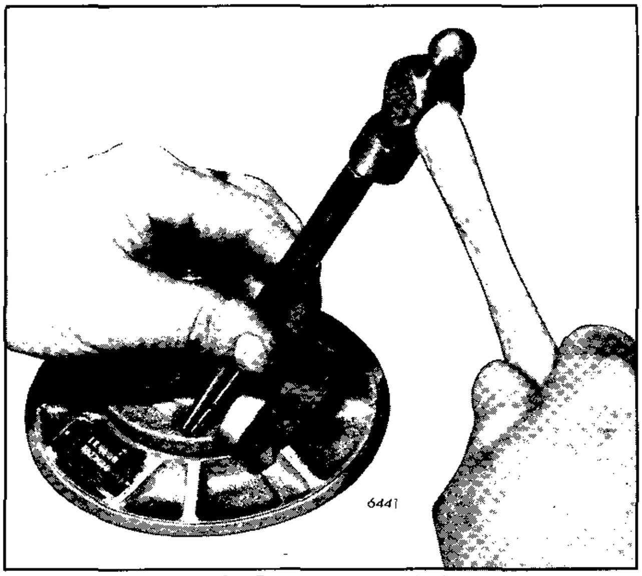


Fig. 10 - Removing Backplate

Fig. 11 - Removing Seal Ring from Center Housing

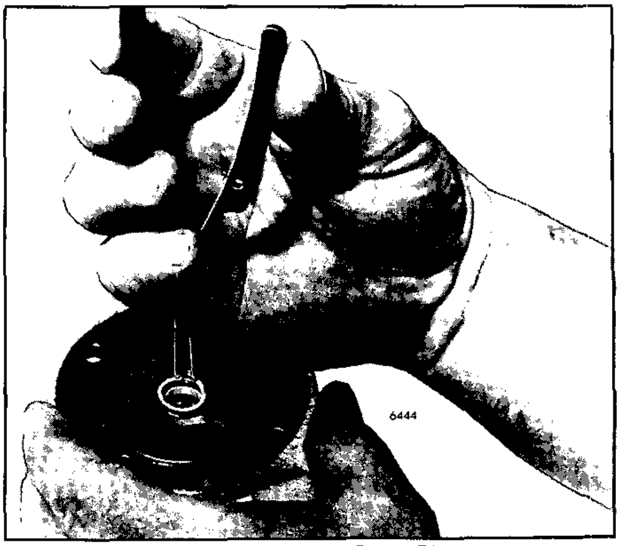


Fig. 13 - Removing Snap Ring.

will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

Clean the oil passages in the thrust bearing and thrust collar with compressed air.

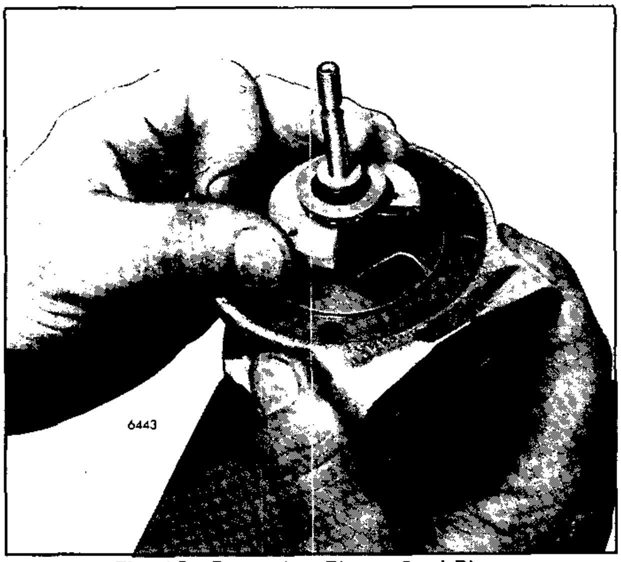


Fig. 12 - Removing Piston Seal Ring

Inspection

Refer to the Turbocharger Technicians' Guide 7SE374 for further turbocharger information.

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads in the center section turbine and compressor housings.

Visually inspect the turbine and compressor wheels and both housings for contact or signs of rubbing. Check compressor wheel bore for galling.

Measure the concentricity between the large and small turbine shaft diameters with a dial indicator and Vee-block. Limit of eccentricity is .01 mm (.0006") total indicator reading. Replace if the measurement is excessive.

NOTICE: Do not attempt to straighten a bent shaft.

Examine the turbine shaft for any damage to the ring seal groove, bearing journals or thread damage. The diameter of a new shaft journal is 10.15-10.16 mm (.3997-.4000") - (Fig. 14).

Examine the bore diameter in the center housing for any scoring or galling. The seal bore diameter of a new center housing is 17.76-17.81 mm (.6990-.7010"). Also, examine the turbine shaft seal searing surface for damage. The bearing bore diameter of a new center housing is 15.80-15.81 mm (.6220-.6223") - (Fig. 15).

Inspect the compressor backplate assembly for any contact with the compressor wheel or damage to the piston seal ring seating surface (Fig. 16). The seal bore diameter in the compressor backplate is 12.69-12.71 mm (.4995-.5005").

All passages in the compressor housing, exhaust turbine housing and oil passages in the center housing must be free of any obstructions and cleaned prior to assembly.

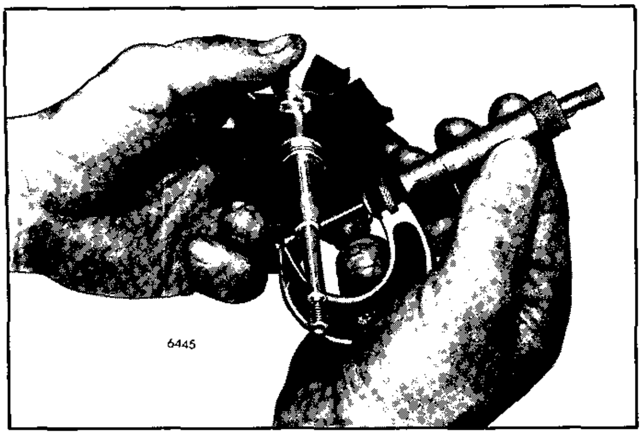


Fig. 14 - Measuring Turbine Shaft

Examine the water cooled exhaust turbine housing for any cracks or leaking freeze plugs. Water pressure testing of the turbine housing may be required to determine leaks. Suitable plugs and plates must be fabricated to complete test, and do not exceed 276 kPa (40 psi) while performing the test.

Minor surface damage may be burnished or polished. Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts. It is recommended that the seal ring, piston rings, bearings, snap rings, lockplates and thrust plate be replaced at time of disassembly.

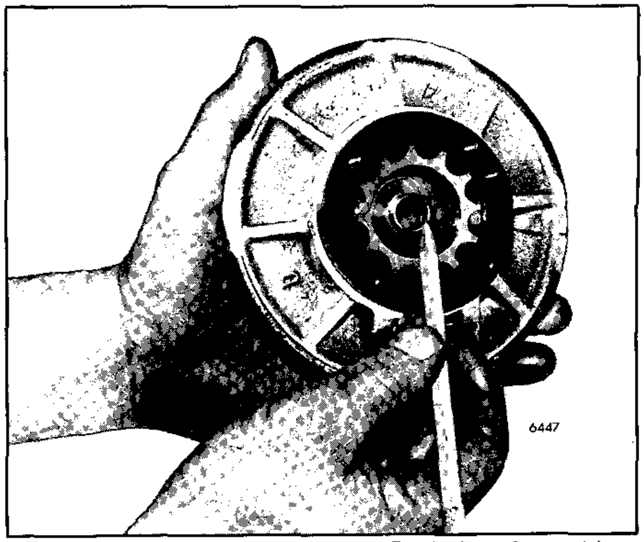


Fig. 16 - Inspecting Compressor Backplate Assembly

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or foreign material.

All bolts must use a locking compound on the threads of the bolt, with the exception of the center housing to backplate bolts, which use lock plates. High temperature adhesive 3M No. 2451 or equivalent, must be applied sparingly.

Refer to Fig. 6 for parts orientation and proceed as follows:

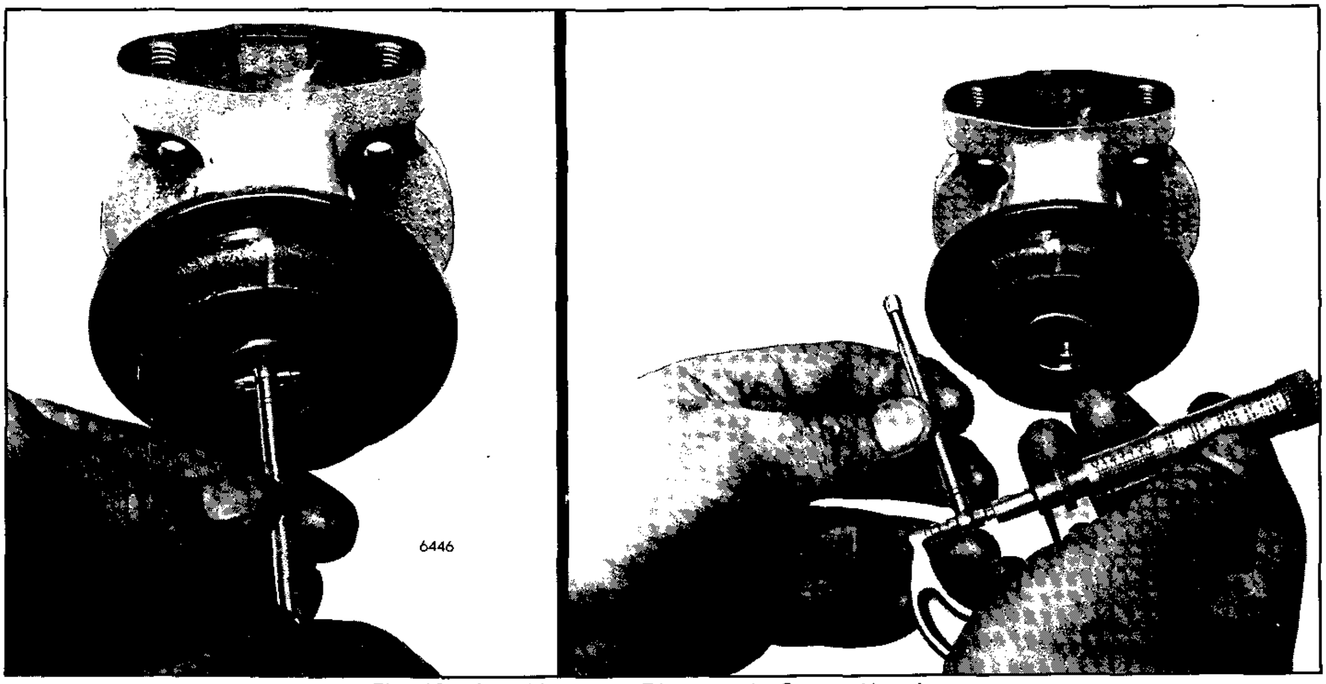


Fig. 15 - Checking Bore Diameter in Center Housing

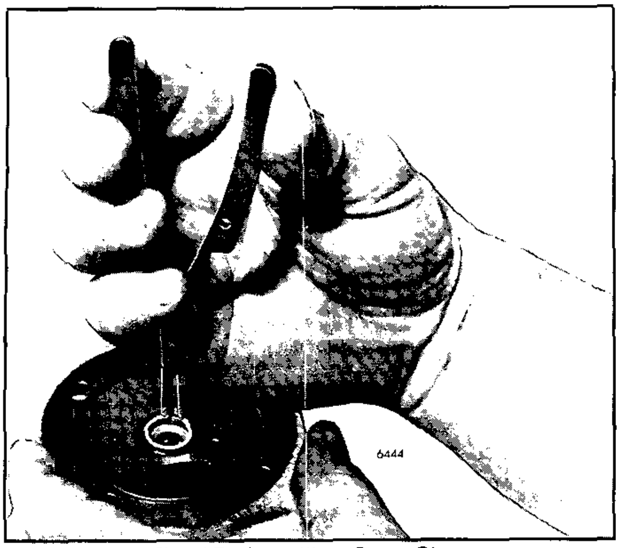


Fig. 17 - Installing Snap Ring

1. Install a new snap ring, bearing and snap ring in the turbine end of the center housing using snap ring pliers J 28507 (Fig. 17).
2. Install a new snap ring, bearing and snap ring in the compressor end of the center housing, using snap ring pliers J 28507.
3. Lubricate the bearings in the center housing with clean engine oil.
4. Fill the piston ring groove in the turbine wheel shaft with silicone grease. Carefully install the new piston ring seal over the shaft bearing journals and into the groove on the shaft (Fig. 18).
5. Position the wheel shroud on the wheel of the shaft assembly and insert the shaft assembly into the center housing as far as it will go (Fig. 19).

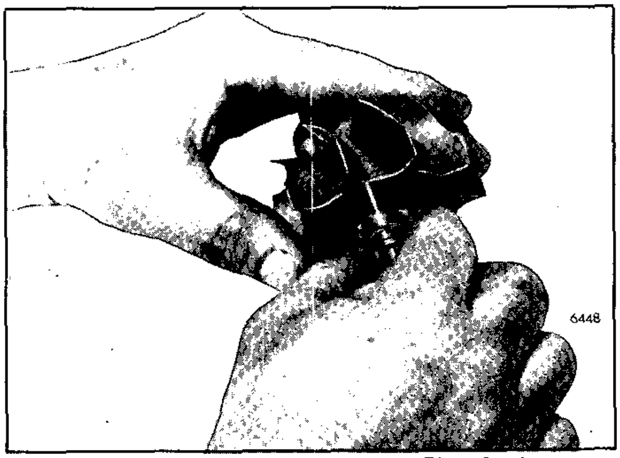


Fig. 18 - Installing New Piston Ring Seal

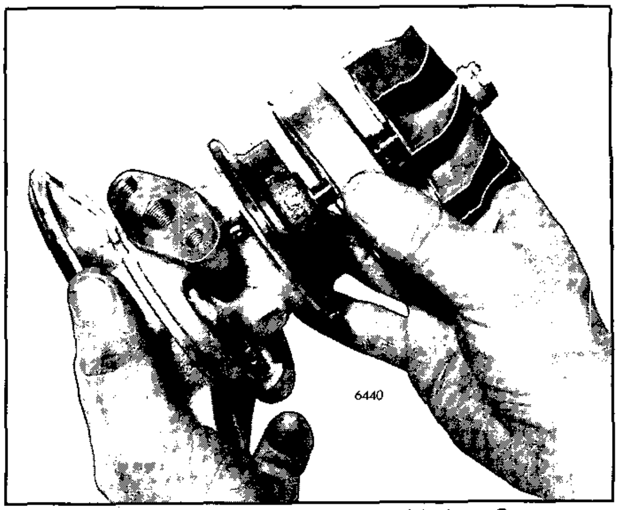


Fig. 19 - Positioning Shaft Assembly into Center Housing

NOTICE: Be careful not to scuff or scratch the bearings when installing the shaft and do not force the piston ring into the center housing bore.

6. Place the turbine wheel shaft assembly, shroud and center housing upright in holding fixture J 29086-3.

NOTICE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

7. Lubricate the thrust collar and thrust bearing with clean engine oil and install the thrust collar on the shaft of the turbine wheel assembly. Then, install the thrust bearing in the groove of the collar and slide the assembled parts down against the center housing so that the pins engage the holes in the thrust bearing (Fig. 20).
8. Install a new piston ring seal on the thrust collar.

NOTICE: To avoid breakage, do not force the piston ring into place.

9. Install a new seal ring in the groove at the compressor end of the center housing (Fig. 21).
10. Install the backplate assembly over the shaft and carefully guide the piston ring on the shaft into the backplate bore, ring gap first.
11. Align the previously marked compressor backplate assembly to the marks on the center housing and install the bolts and new lock plates. Tighten the bolts to 11-15 N·m (100-130 lb-in) torque and bend the lock plate tabs up against the side of the bolt head with a drift and hammer (Fig. 22).
12. With the compressor wheel at room temperature, position it over the shaft.

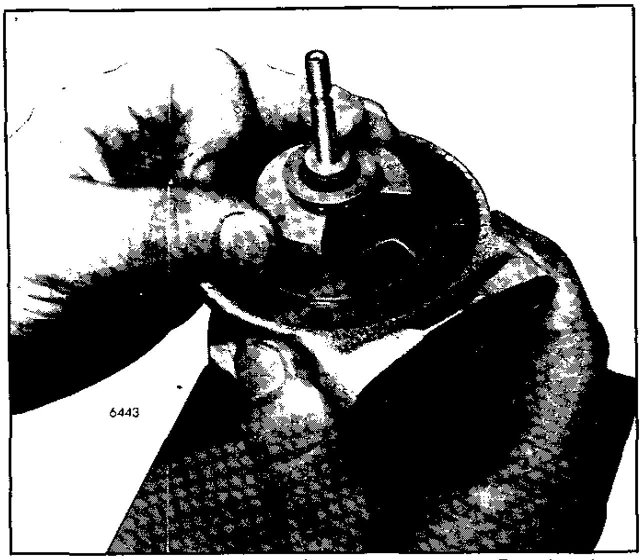


Fig. 20 - Installing Thrust Collar and Thrust Bearing into Center Housing

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install the locknut on the shaft. Tighten the 1/4″-28 nut to 2 N·m (18-20 lb-in) torque above the drag torque required to bottom the locknut (Fig. 23). Bottoming of the locknut will be indicated by the sharp increase above the drag torque observed while running the nut down.

14. Retighten the locknut with a tee-handle and double universal with socket an additional 90° of tightening rotation of the nut. This additional tightening will result in stretching the shaft .14 mm (.0055″) to .16 mm (.0065″) in length (Fig. 24).

15. Check the bearing axial end play:
    a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in (Fig. 25).
    b. Fasten the dial indicator and magnetic base J 7872-2 to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side.
    c. Move the shaft axially back and forth by hand. The total indicator reading should be between .03-.08 mm (.001-.003″). If the total dial indicator readings do *not* fall within the specified limits, repair or replace the rotating assembly.

16. Position the turbine housing as marked at disassembly against the center housing and secure it in place with clamps and bolts. Tighten the bolts to 16-19 N·m (140-170 lb-in) torque.

17. Position the compressor housing as marked at disassembly against the center housing and secure it in place with clamps and bolts. Tighten the bolts to 11-15 N·m (100-130 lb-in) torque.

18. Check the shaft radial movement:
    a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange.
    b. Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

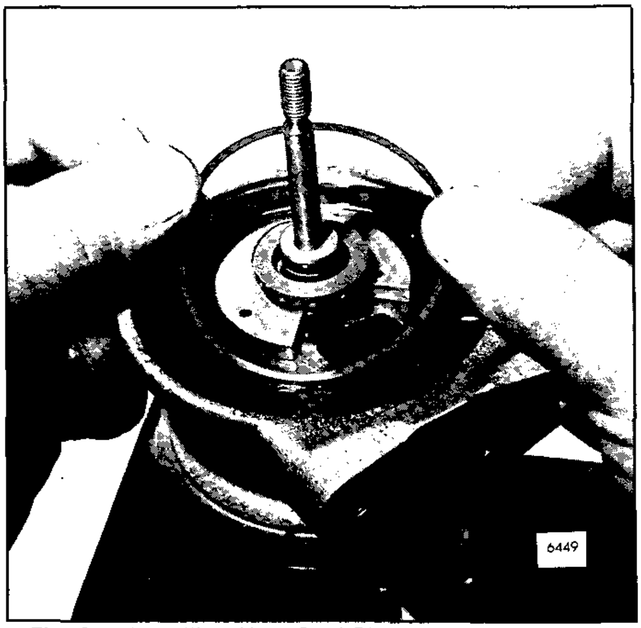
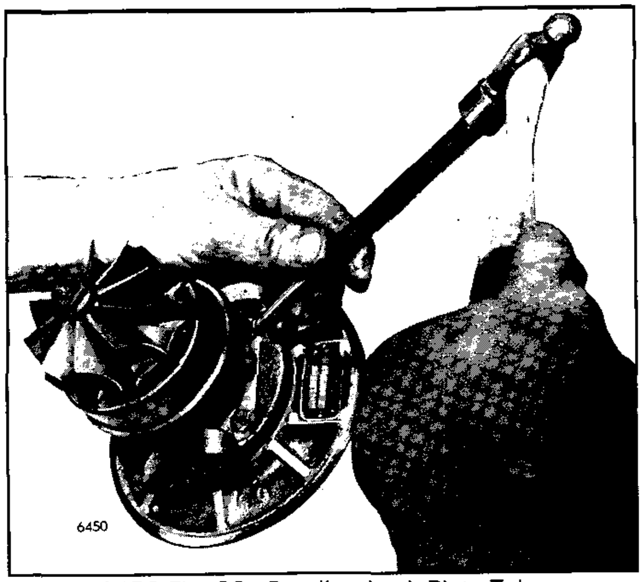


Fig. 21 - Installing New Seal Ring in Center Housing



6450 Fig. 22 - Bending Lock Plate Tabs

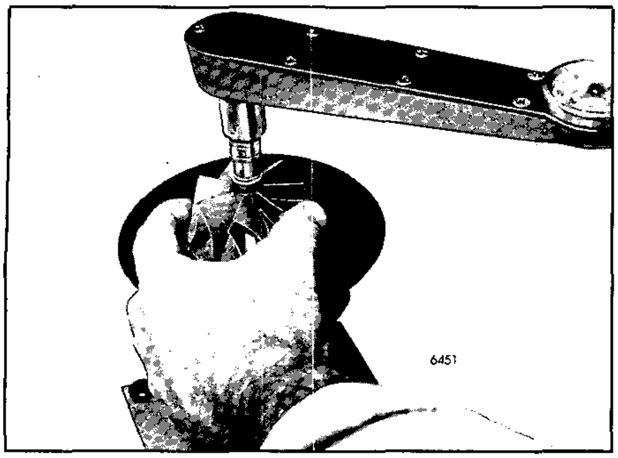


Fig. 23 - Tighten Locknut

c. Insert the extension rod J 7872-1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTICE: Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .08-.17 mm (.003-.0065"). If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

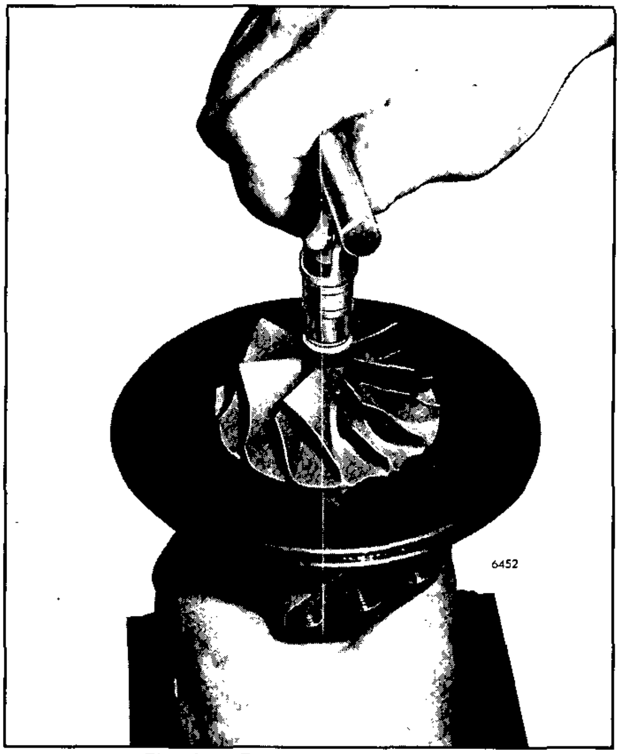


Fig. 24 - Retightening Locknut

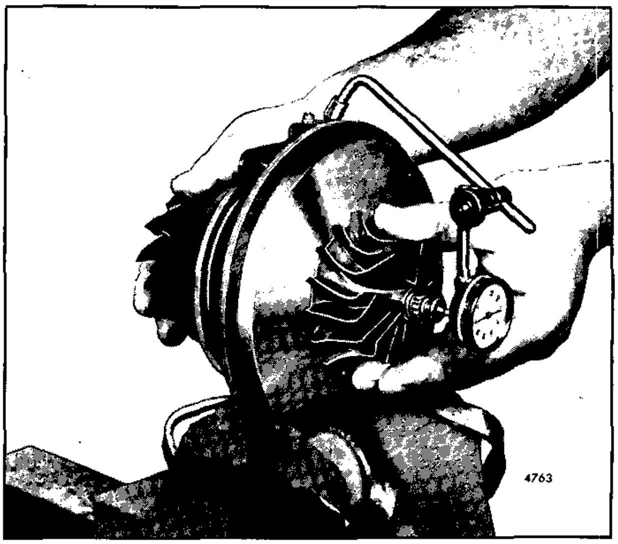


Fig. 25 - Checking Bearing Axial End Play

19. If it is to be stored, lubricate the center section unit internally and install protective covers on all openings.
20. Stamp the letter "R" and rebuild date in the lower left-hand corner of the name plate to identify that the turbocharger had been reworked.

Install Turbocharger

1. If needed, attach a suitable lifting sling to the turbocharger assembly.
2. Remove all protective covers from the compressor inlet and outlet openings, the turbine housing inlet and outlet openings and lubrication inlet and outlet openings.
3. Remove the protective coverings from the engine openings that were installed at the time the turbocharger assembly was removed.
4. Position the turbocharger assembly above the cross-over exhaust manifold, using a new gasket, align the coolant openings in the gasket and install the turbocharger assembly on the manifold. Install the special flat washers and locknuts with anti-seize compound and tighten the nuts to 58-66 N·m (43-49 lb-ft).
5. Connect the exhaust outlet elbow and tighten the marmon flange clamp nut.

6. Connect the raw water hose at the exhaust outlet elbow and tighten the clamps.
7. Connect the compressor outlet hose to the air intake piping, tighten the hose clamp.
8. Install oil drain tube, bolts, clamps and hose using a new gasket. Tighten the clamps. Torque the bolts to 41-47 N·m (30-35 lb-ft)
9. Prior to connecting the oil supply line, fill the center housing section with a few ounces of clean engine oil. Connect the oil supply line to the fitting in the center housing, tighten the nut.
10. Connect the engine coolant return line hose and clamps, tighten the clamps.
11. Connect the air silencer, clamps and retainer support bracket bolt, tighten the clamps and bolt. Refer to Section 3.2.
12. Fill the engine cooling system as outlined in Section 5 and with the recommended coolant as outlined in Section 13.3. Check for any leaks.
13. Open any valving that was secured, that supplies raw water to the pump.
14. Check all the air, water and exhaust connections for leaks.
15. Operate the engine at rated output and listen for sound of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTICE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assemlby jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER (Schwitzer)

The Schwitzer turbocharger, Model 3LM403, (Fig. 3) is comprised of a centrifugal compressor which shares a bearing system and rotor shaft with an exhaust gas driven turbine. *The turbocharger boosts the intake* pressure of an engine above that which would prevail if the engine were naturally aspirated. The rotating assembly is supported radially by a free-floating, pressure lubricated, sleeve type bearing. Axial end play is controlled by a stationary pressure lubricated thrust bearing, with attendant hardware in the compressor end of the bearing housing.

The oil cavity is separated from the air and exhaust chambers by piston type seal rings located in the cylindrical bores at both axial extremities of the bearing housing.

The external configuration of both the Schwitzer and the Airesearch turbochargers are identical and hardware connections will not change. However, the internal components are different.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an internal oil gallery from the engine cylinder block to the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearing, thrust bearing and thrust sleeve. The oil returns by gravity to the engine oil pan through an internal oil gallery from the bottom of the turbocharger center housing to the cylinder block.

Periodic Inspection

> **NOTE:** A turbocharger compressor inlet shield, J 26554, (Fig. 1) is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other safety practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

> **NOTE:** Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Turbocharger* in Section 3.0. Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

> **NOTE:** Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust

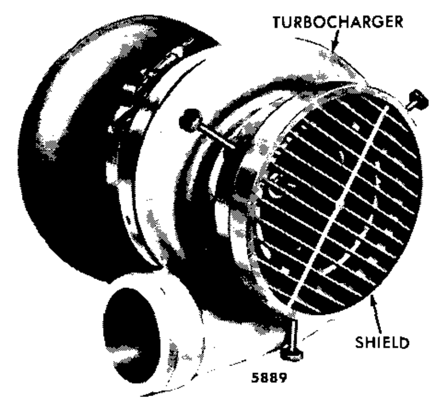


Fig. 1 - Inlet Shield

TROUBLE SHOOTING CHARTS

CHART 1

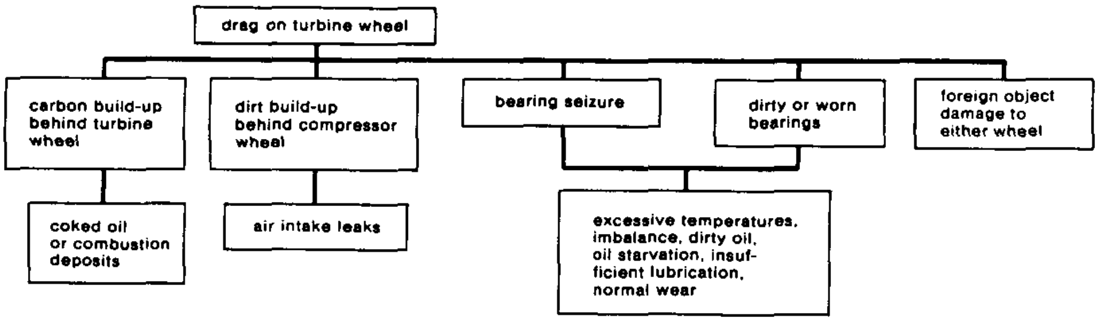


CHART 2

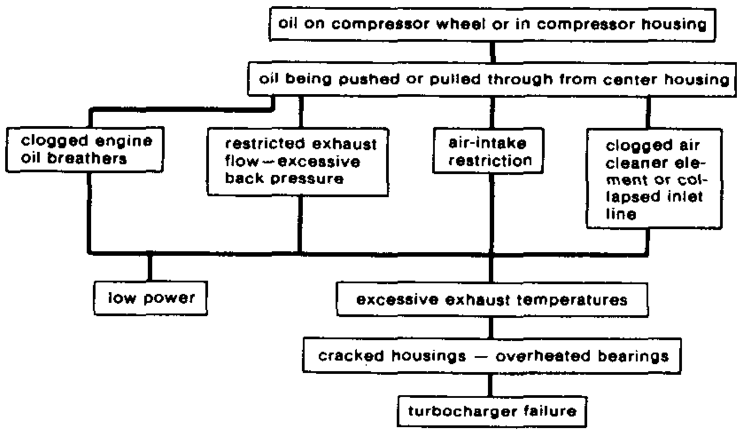


Fig. 2 · Inspection Checks for Turbocharger

ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1, Fig. 2. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Check for signs of oil leaking from the turbocharger housing. Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2, Fig. 2.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that the turbocharger oil drain is unrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove the air intake ducting. Inspect inside of the ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, the impeller cavity behind the impeller, and the backplate annulus with a suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of "Spot-Check" developer type SKD-MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm-up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot-Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. With the air cleaner removed loosen the two hose clamps between the air cleaner adaptor to air inlet elbow.

2. Remove four attaching bolts and lift the adaptor from the turbo to intake connector.

3. Loosen the hose clamp at the turbocharger to inlet elbow and remove the elbow.

4. Loosen the two hose clamps securing the cover sleeve to the connector (turbocharger to air intake manifold).

5. Loosen the exhaust tube clamps at the exhaust manifold to turbocharger inlet tubes. Remove the clamps and tubes.

6. Remove the turbocharger to cylinder block attaching bolts and lift the turbocharger from the block.

7. Remove the turbocharger to cylinder block oil ring seal from the block and discard it.

8. Cover the air inlet, oil connections and exhaust openings on the engine to prevent the entry of foreign material.

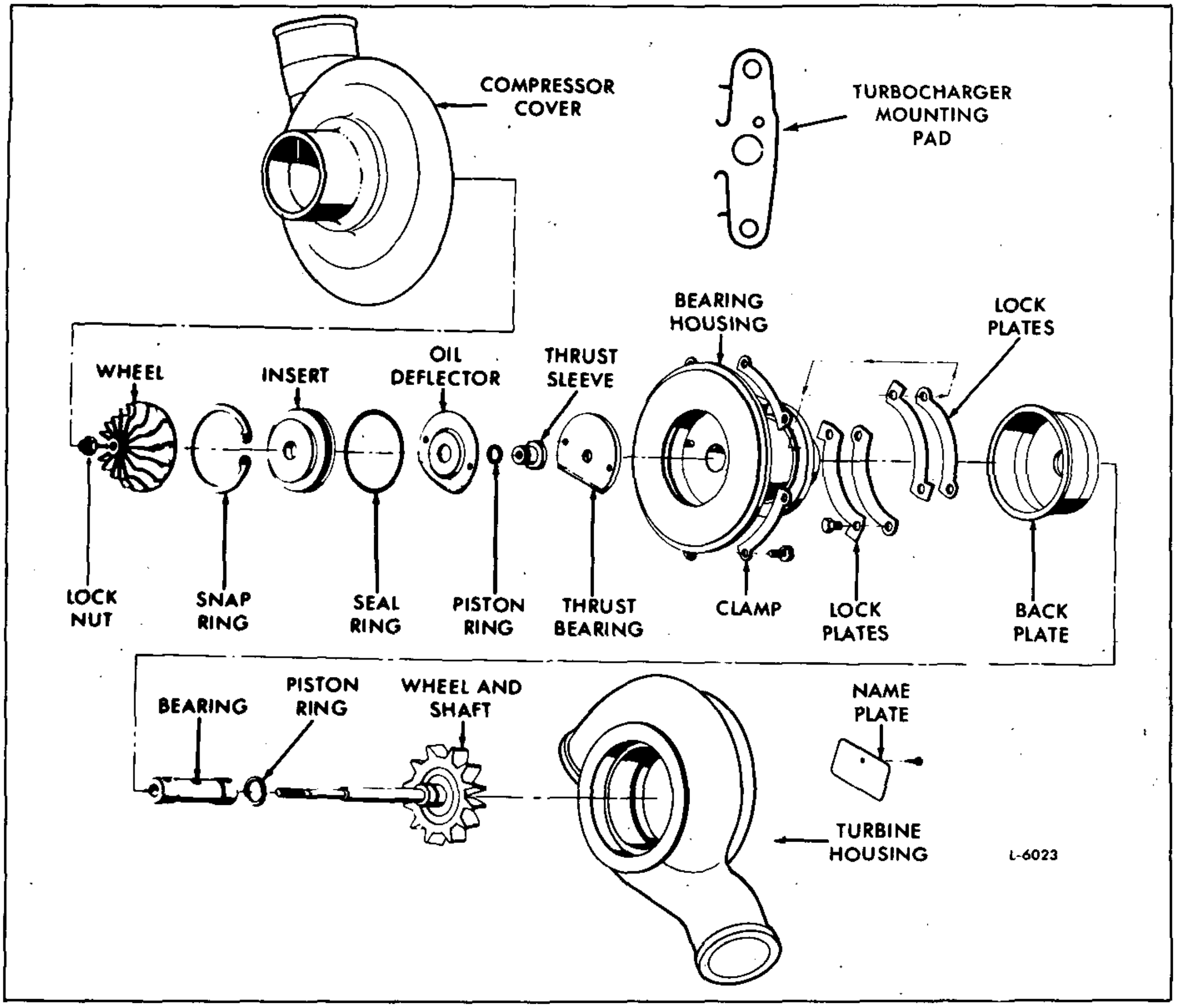


Fig. 3 - Model 3LM Turbocharger and Relative Location of Parts

Disassemble Turbocharger

CAUTION: During disassembly it is recommended that safety glasses be used.

1. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

NOTE: Exercise care when removing the compressor housing and turbine housing from the bearing housing to prevent damage to the compressor and turbine wheels.

2. Support the turbine housing and bend back the lock tabs on the lock plates. Then remove the four screws, two lock plates and two clamps.

3. Remove the rotating assembly and compressor cover as an assembly out of the turbine housing and invert it and place it on a work bench with the turbine wheel facing up.

4. Remove the eight screw and lock washer assemblies and four clamps. Then remove the rotating assembly from the compressor cover.

5. With the turbine wheel lug of the rotating assembly in a 1" wrench (Fig. 4), remove and discard the compressor wheel lock nut.

6. Remove the compressor wheel from the turbine shaft assembly by hand (Fig. 5). The wheel is a slip fit on the shaft.

7. Remove the external snap ring from the compressor end of the bearing housing (Fig. 6). Use medium size

internal snap ring pliers and restrain the ring with a shop cloth to prevent injury, in the event the ring goes astray.

8. Remove the compressor insert from the bearing housing by prying evenly and gently with screw drivers placed under the lip of the insert (Fig. 7).

NOTE: *If the insert tilts and binds, tap it back into place and repeat the procedure. Do not force* the insert from the bearing housing.

9. Remove the oil deflector, outer piston ring, thrust sleeve, thrust bearing (discard) and inner piston ring from the cavity in the bearing housing.

NOTE: Do not remove the dowels from the bearing housing.

10. Tap the turbine shaft assembly gently with a plastic faced mallet to release it from the bearing housing (Fig. 8).

11. Remove the turbine wheel and shaft assembly. The shaft should slip freely out of the bearing after the initial release by tapping.

12. Remove and discard the turbine shaft bearing from the bearing housing bore (Fig. 9).

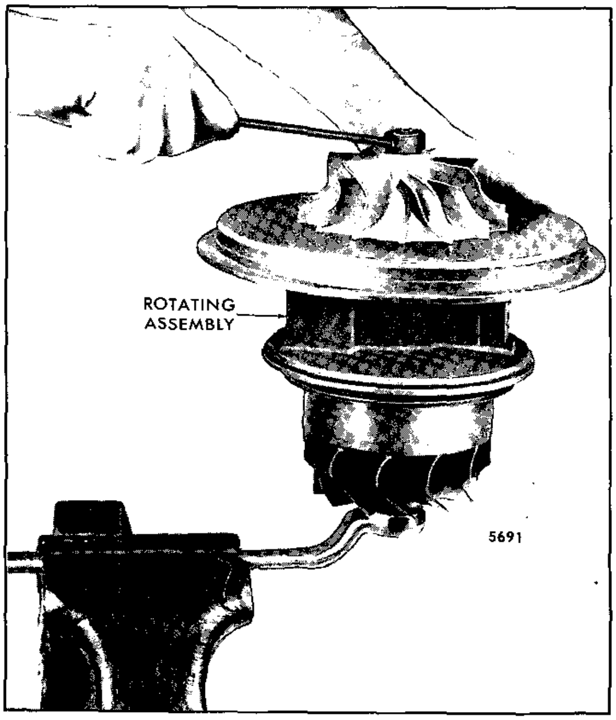


Fig. 4 - Removing Compressor Wheel Lock Nut

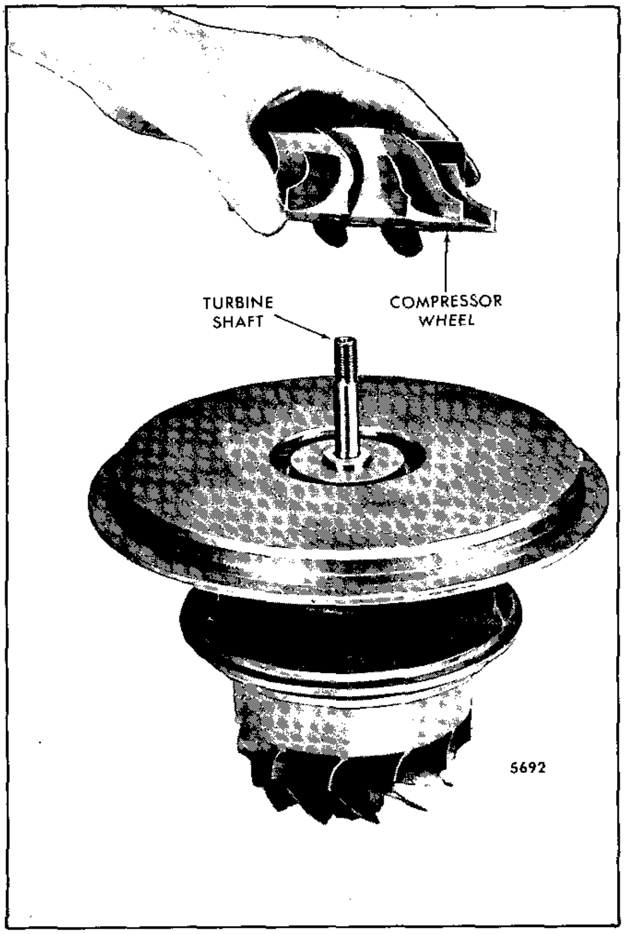


Fig. 5 - Removing Compressor Wheel from Turbine Shaft

13. Separate the backplate from the bearing housing.

NOTE: If the seal ring bore in the bearing housing is encrusted with carbon, preventing removal of the bearing components, scrape away the carbon with a sharp-edged tool. Do not scratch or gouge the seal ring bore surface.

14. Remove and discard the seal ring from the turbine wheel-and-shaft by prying and breaking with a screw driver. Take care not to mar the hub or groove surfaces of the turbine wheel.

Cleaning Procedures

1. Bearing Housing and Dowel Assembly:

a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

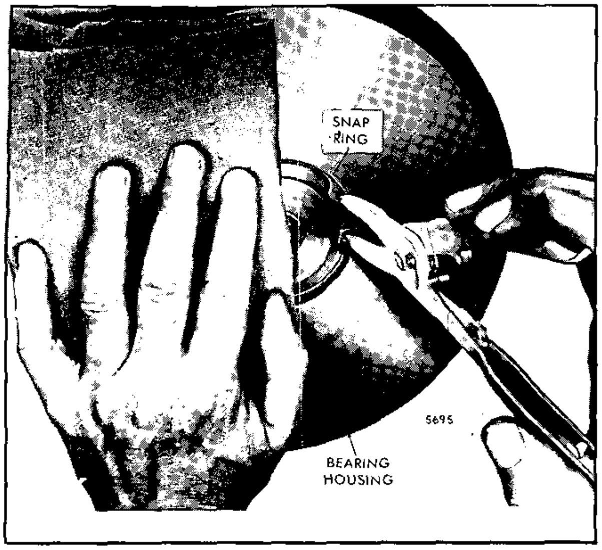


Fig. 6 - Removing External Snap Ring from Bearing Housing

b. Immerse briefly in safety solvent to remove any traces of oily residue.

c. Dry with clean compressed air, again taking care that all drilled oil passages are thoroughly cleaned.

d. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

2. Compressor Wheel:

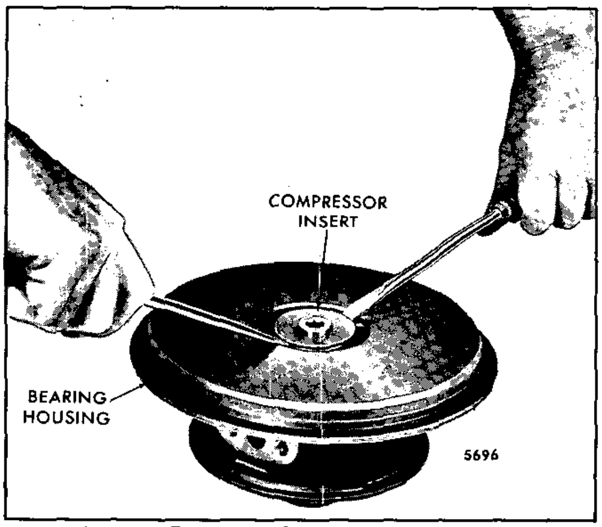


Fig. 7 - Removing Compressor Insert from Bearing Housing

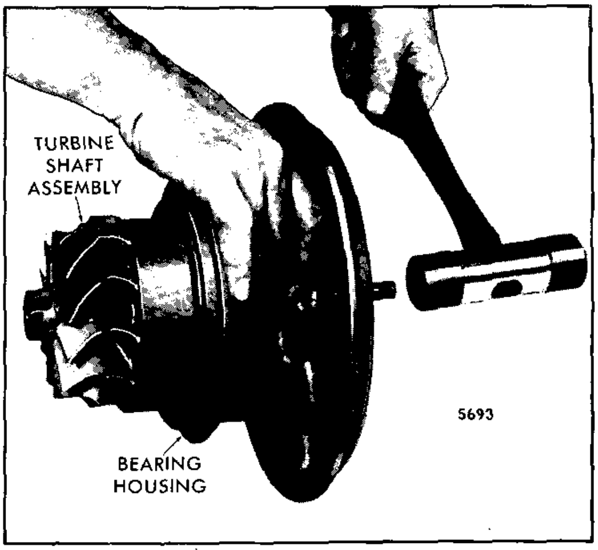


Fig. 8 - Tapping Turbine Shaft Assembly from Bearing Housing

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

3. Turbine Wheel-and-Shaft Assembly:

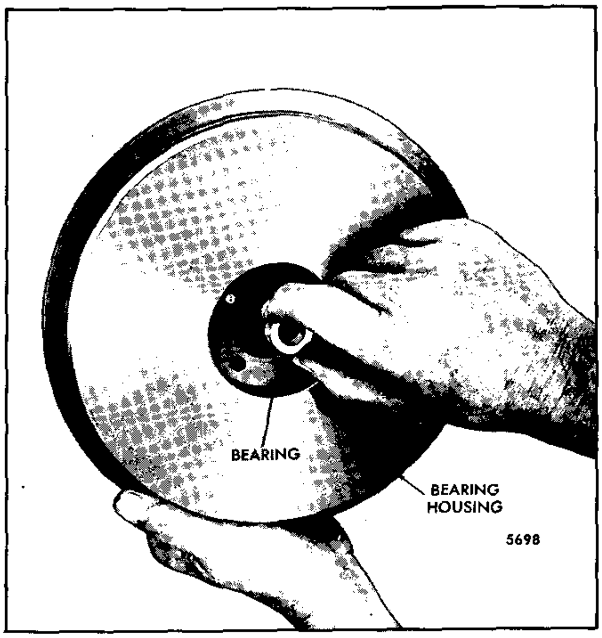


Fig. 9 - Removing Turbine Shaft Bearing from Bearing Housing

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. Mask the entire shaft section with either appropriately sized rubber hose or adhesive backed cloth tape.

d. Vapor blast or dry hone the entire turbine wheel and the hub to total cleanliness, taking care not to concentrate on the seal ring groove.

e. Remove the masking material.

f. Mount the small diameter shaft section in a lathe chuck, taking care not to mar the shaft surface. *Lightly* polish the bearing journal section of the shaft, at 300 to 600 rpm, with 400 grit abrasive paper and clean engine oil.

g. Reimmerse briefly in clean safety solvent, agitating moderately by hand to help loosen any remaining particles of foreign material.

h. Dry with clean compressed air.

i. Oil the shaft surfaces liberally to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

4. Compressor Housing:

a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

b. Immerse briefly in safety solution to remove any traces of oily residue.

c. Dry with clean compressed air.

d. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

5. Turbine Housing and Turbine Backplate:

a. Immerse briefly in safety solvent to remove any traces of oily residue.

b. Dry with clean compressed air.

c. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

6. Clamp Bands:

a. Immerse in safety solvent until foreign material deposits have been softened or dissolved, agitating moderately and occasionally by hand.

b. Dry with clean compressed air.

c. Wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

7. Small Internal Parts:

a. Immerse briefly in clean safety solvent to remove any traces of oily residue.

b. Wipe dry with a clean shop rag.

c. Oil liberally to prevent rust and wrap *immediately* in a clean, dry plastic bag until inspection and reuse.

Inspection

1. Bearing Housing and Dowel Assembly:

a. Inspect visually for evidence of cracks and fractures, pitting (as from corrosion or hot gas erosion) of gasket and other machined surfaces, and warpage of the turbine end flange. Replace if any of the above conditions are excessive.

b. Closely inspect the bearing bore visually for evidence of surface distress. The condition of the bearings that were removed during disassembly will serve as a good indicator of probable bore condition. Replace if the bore condition is substandard. The maximum bore diameter is 19 mm (.7505").

c. Install the turbine seal ring in its bore, inspect

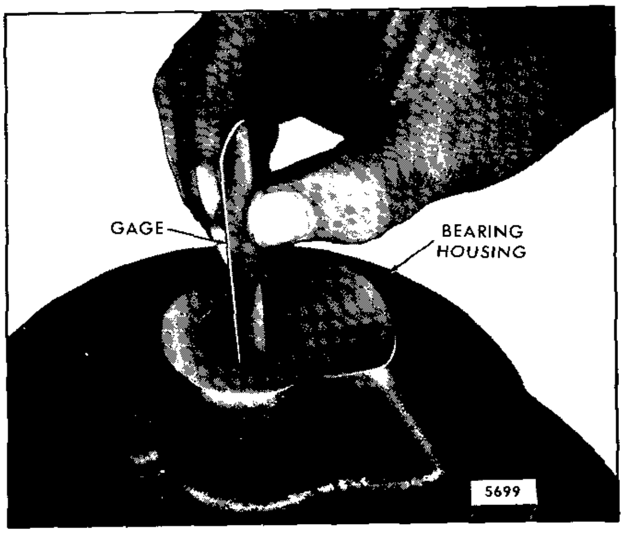


Fig. 10 - Checking Turbine Seal Ring Gap in Bearing Housing

visually for full circle contact, and measure the ring gap with a feeler gage (Fig. 10). The gap range is .05 mm (.002 ") to .17 mm (.007 "). Replace if the ring fit is faulty.

NOTE: Do not attempt to restore the bore condition by reaming or honing.

2. Compressor Wheel:

Inspect visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the backplate. Replace if this damage is present. Slightly nicked vanes are acceptable.

NOTE: Do not attempt to straighten bent vanes.

3. Turbine Wheel and Shaft Assembly:

a. Inspect the wheel visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the back face. Replace if damaged.

NOTE: Do not attempt to straighten bent vanes.

b. Inspect the hub visually for evidence of smearing (as from high speed contact with the bearing housing bore) and for deterioration of the seal ring groove. Replace if damage is excessive.

c. Inspect bearing journals visually for evidence of other than superficial deterioration (as from a bearing failure). Replace if journal condition is sub-standard. The minimum journal diameter is 11.176 mm (.4400").

d. Measure the concentricity between the large and small turbine shaft diameters with a dial test indicator and vee-block (Fig. 11). Limit of eccentricity is .01 mm (.0006 ") total indicator reading. Replace if the measurement is excessive.

NOTE: Do not attempt to straighten a bent shaft.

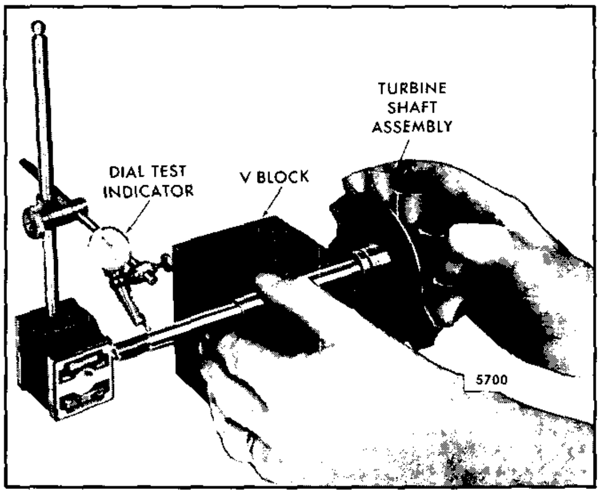


Fig. 11 - Measuring Concentricity Between Large and Small Turbine Shaft Diameters

4. Compressor Housing:

Inspect visually for evidence of contour damage (as from high speed wheel contact). Replace if damaged.

5. Turbine Housing and Backplate:

Inspect visually for evidence of contour damage (as from high speed wheel contact) and for evidence of excessive heat damage, to internal and flanged surfaces, such as cracking, pitting or warpage. Replace if damaged.

6. Small Internal Parts:

a. Install the compressor seal ring in the insert bore, inspect visually for full circle contact and measure the ring gap with a feeler gage. Gap range is .05 mm (.002 ") to .17 mm (.007 "). Replace the insert if the ring fit is faulty.

NOTE: Do not attempt to restore bore condition by reaming or grinding.

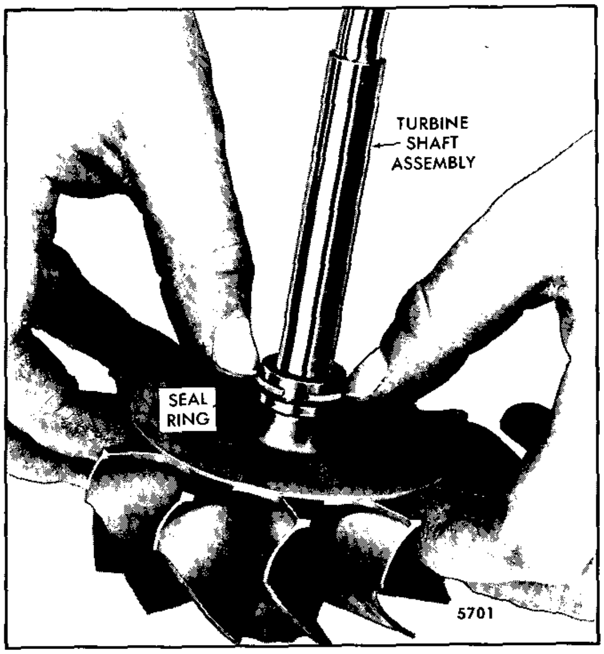


Fig. 12 - Installing Seal Ring on Turbine Shaft

b. Inspect both thrust rings visually for evidence of wear and scratching. Replace if damaged.

Assemble Turbocharger

1. Place the turbine housing in a vise with the six threaded holes facing up.

2. Lubricate a new piston ring with clean engine oil and install it in the ring grooves of the wheel and shaft assembly (Fig. 12).

NOTE: Do not over expand the ring.

3. Position the bearing housing, turbine end up (Fig. 13). Then install the turbine backplate.

NOTE: The backplate has no attachment to the bearing housing. Its position is fixed when the bearing housing and turbine housing are clamped together.

4. Lubricate the piston ring area of the shaft and

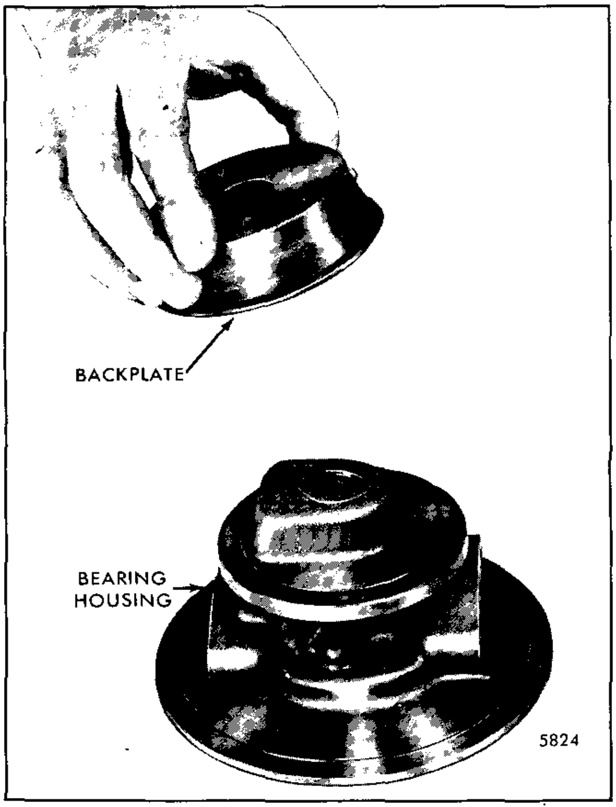


Fig. 13 - Assembling Bearing Housing and Backplate

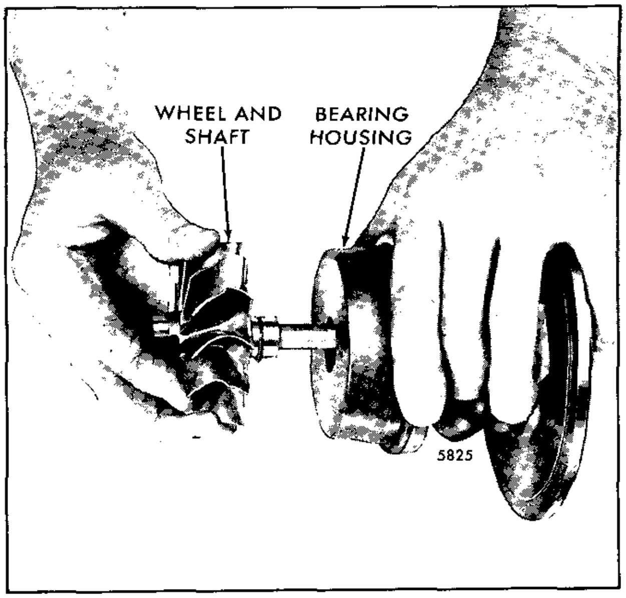


Fig. 14 - Installing Shaft and Wheel Assembly Through Back Plate into Bearing Housing

wheel assembly with clean engine oil and install it through the backplate and into the bearing housing (Fig. 14).

NOTE: Be careful and avoid damage to the piston ring.

5. Holding the end of the shaft, to prevent the shaft and wheel assembly from falling out of the bearing housing, install the assembly in the turbine housing wheel end down.

6. Lubricate the inner and outer diameter of the bearing. Then install the bearing down over the shaft and into the bearing housing bore.

7. Lubricate the thrust faces on both side of the thrust bearing and install the bronze side of the bearing over the shaft and groove pins, engaging the pins to the holes in the thrust bearing (Fig. 15).

8. Install the oil deflector on the thrust sleeve.

9. Lubricate a new piston ring and install it on the thrust sleeve.

NOTE: Do not over expand the piston ring.

10. Lubricate a new seal ring and install it in the groove on the insert.

11. Lubricate the thrust sleeve and install the small end into the hole of the insert from the concave side of the insert. Be careful to avoid damage to the piston ring.

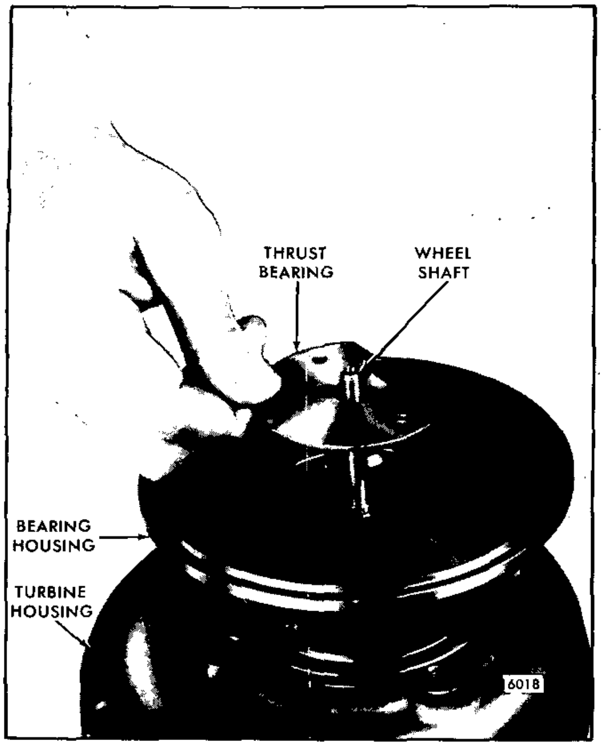


Fig. 15 - Install Thrust Bearing in Bearing Housing

12. Lubricate the thrust cavity in the bearing housing and install the insert, oil deflector and thrust sleeve assembly over the shaft and into the bearing housing (Fig. 16). Align the oil deflector to mate with the oil drain cavity in the bearing housing.

> **NOTE:** It may be necessary to tap the insert with a soft hammer to seat it completely. Do not damage the seal ring.

13. Install the external snap ring in the compressor end cavity of the bearing housing. Be sure the ring seats fully in the groove, by twist-prying against the insert rim with a screw driver.

> **CAUTION:** To prevent eye or facial injury, use a rag to snub the ring should it slip from the pliers during compression (Fig. 6).

14. Mount a dial indicator on the bearing housing with the stem resting on end of the shaft. Make sure that the turbine end of the bearing housing is properly seated in the turbine housing. Then move the shaft vertically to determine turbine wheel contour clearance. It must be .46 mm (.018 ") to 1.24 mm (.049 ").

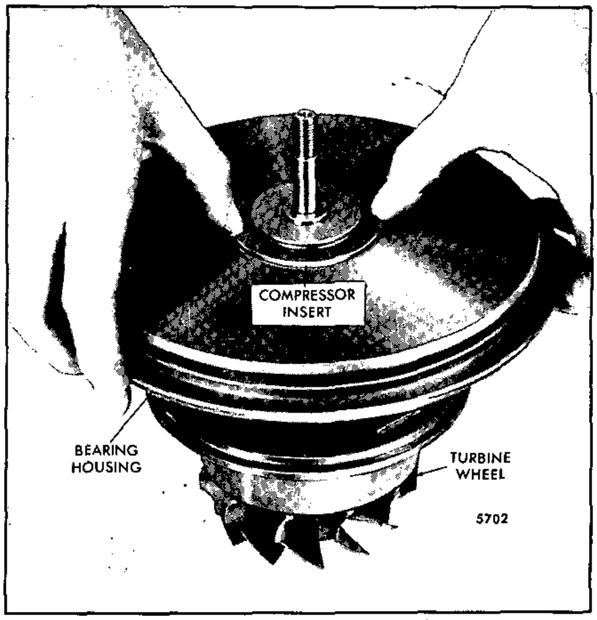


Fig. 16 - Installing Compressor Insert in Bearing Housing

If the clearance is not within these tolerances, disassemble the unit to determine the cause. Look for burrs, dirt particles or incorrectly assembled parts. Reassemble and check the contour clearance. If it is still out of tolerance, do not attempt to use.

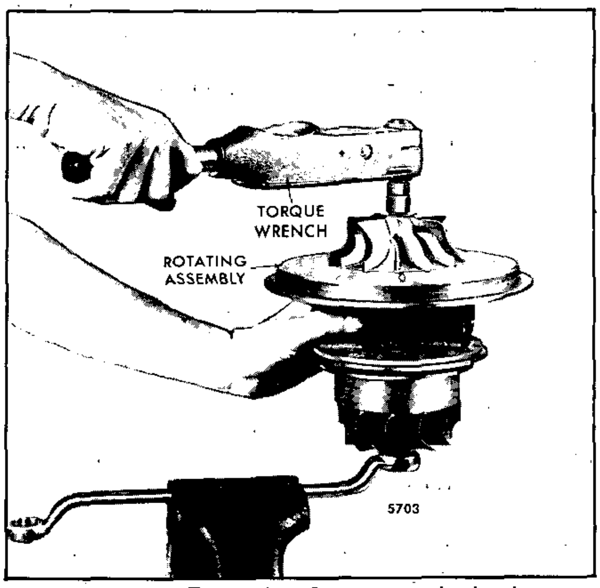


Fig. 17 - Tightening Compressor Locknut

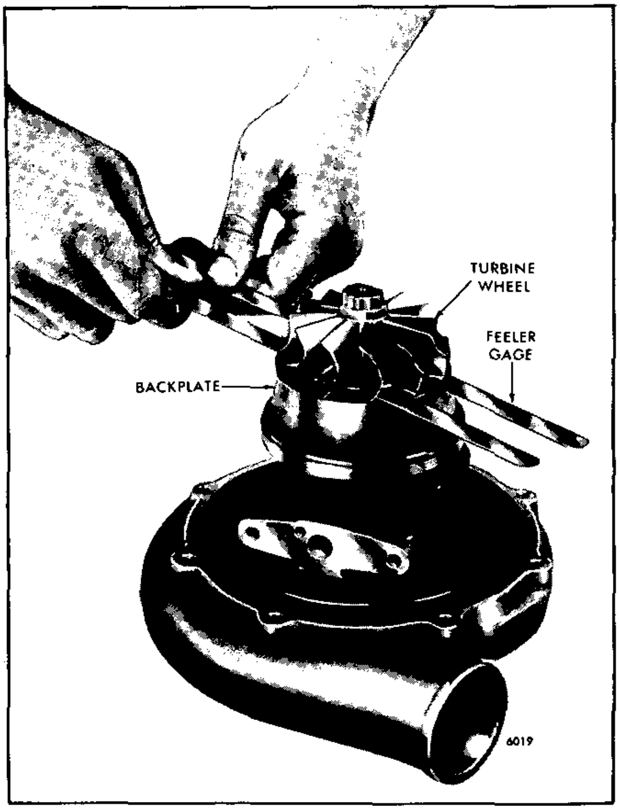


Fig. 18 - Checking Turbine Wheel to Backplate Clearance

15. Install the compressor wheel on the shaft.

16. Lubricate the back face and threads of the lock nut with anti-seize compound. Install the lock nut on the shaft finger tight (until elastic of nut engages shaft threads) and place an 11/16" socket on the turbine wheel lug to prevent the shaft from turning. Use a torque wrench to tighten the 5/16"-24 lock nut to 18 Nm (13 lb-ft) torque (Fig. 17).

17. Mount the dial indicator on the bearing housing with the stem resting on the end of the shaft to check end play. Total movement must be .05 mm (.002 ") to .12 mm (.005 "). If not within these tolerances, proceed as in Step 14 above.

18. Place the compressor cover on a work bench with the wheel cavity up. Lubricate the pilot diameter with grease or oil and place the rotating assembly in the compressor cover with the turbine wheel up.

19. Check the turbine wheel back clearance by placing two equal feeler gage stacks between the back face of the turbine wheel and the backplate on the opposite sides of the shaft (Fig. 18). Clearance must be .43 mm (.017 ") to 1.24 mm (.049 "). If clearance is not within limits, proceed as in Step 14 above.

20. Install four clamp plates and eight screw and lock washer assemblies. Tighten the screws to 7 Nm (5 lb-ft) torque. Use care not to overtighten the screws.

NOTE: If the compressor cover needs to be re-oriented upon installation on the engine, do not tighten the screws at this point.

21. Turn the unit over and install it in the turbine housing. Apply anti-seize compound to the threads of the six screws. Install the three clamps, three lock plates and six screws. Tighten the screws to 16 Nm (12 lb-ft) torque.

22. Bend the tabs of the lock plates up against one flat of each screw.

NOTE: If the turbine housing needs to be re-oriented upon installation on the engine, do not tighten the screws or bend the lock plate tabs at this point.

23. Inject approximately 7.5 ML (1/4) ounce of clean engine oil into the oil inlet port of the bearing housing.

24. Spin the rotating assembly by hand to assure smooth and free rotation.

25. Seal the completed unit in a clean, dry plastic bag until installed on the engine.

Install Turbocharger

1. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

2. Inspect the intake and exhaust systems leading to the turbocharger to ensure absence of foreign material (even small particles can cause severe damage to the rotating assembly when inducted at high speeds).

3. Remove the oil hole cover and place a oil seal ring in the counterbore in the mounting pad on the cylinder block. Place the turbocharger in position and attach it with two bolts.

NOTE: When a turbocharger is replaced, due to a failure, it should have oil poured into it, before it is installed on the engine. Rotate the shaft to coat the bearings with oil. If the engine has been in storage, pressure lubricate the system through an oil gallery in the cylinder block. This will also pre-lubricate the turbocharger.

4. Position the sleeve spaced equally on the ends of the air inlet housing and the compressor housing. Fasten the sleeve with two clamps.

5. Place a exhaust inlet tube between the exhaust manifold flange and the turbine housing flange at the left bank. Using a clamp at each end of the tube fasten the clamps securely to the manifold and housing flange.

6. Also on the right bank install the inlet tube between the exhaust manifold and turbine housing and attach with clamps as in Step 5.

7. Check all connections, ducts and gaskets for leaks.

8. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut the engine down immediately and correct the cause.

NOTE: Bring the engine to idle speed so that the turbocharger has a chance to slow down before the engine is shut down and oil pressure is lost.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TROUBLE SHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Supply required oil pressure. Clean oil gallery. If trouble persists, overhaul turbocharger.
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or Replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE SYSTEM	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

TROUBLE SHOOTING CHARTS

CHART 1

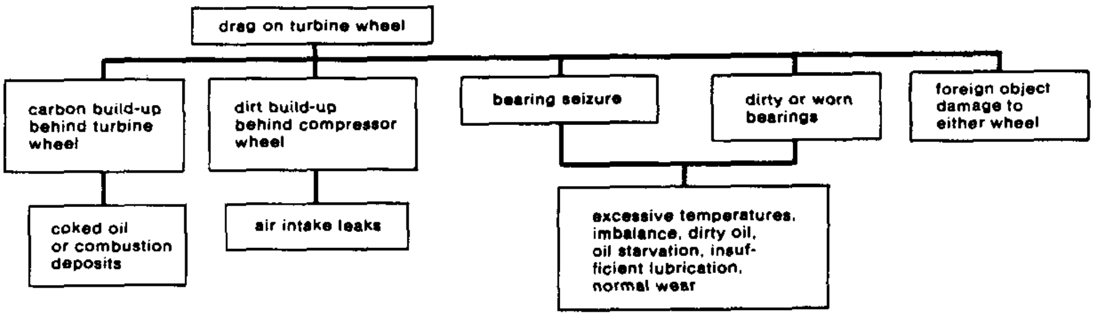
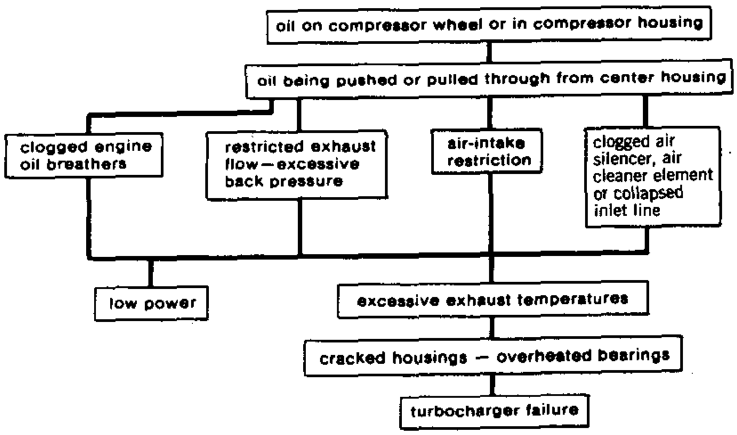


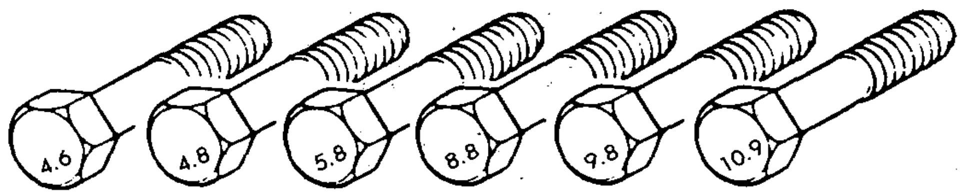
CHART 2



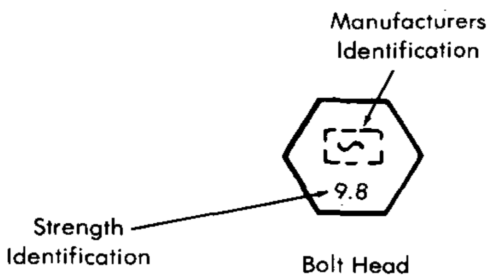
STANDARD METRIC BOLT AND NUT TORQUE SPECIFICATIONS

Thread Size Diameter × MM Per Thread	BOLT CLASSES / TORQUES		
	8.8	9.8	10.9
	Nm/LB-FT	Nm/LB-FT	Nm/LB-FT
M5 × .8	None used	5.0-6.0/3.7-4.4	7.0-8.0/5.2-5.9
M6 × 1.0	" "	10-12/7.4-9.0	13-15/10-11
M8 × 1.25	" "	23-27/17-20	30-34/22-25
M10 × 1.50	" "	46-53/34-39	58-66/43-49
M12 × 1.75	" "	79-91/58-67	101-116/74-86
M14 × 2.0	" "	126-144/93-106	160-184/118-136
M16 × 2.0	" "	192-220/142-162	245-280/181-207
M20 × 2.5	334-384/246-283	None used	478-550/353-406

STANDARD METRIC BOLTS



Metric Bolts — Identification class numbers correspond to bolt strength — Increasing numbers represent increasing strength.



BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (Nm)	TORQUE (lb-ft)
Air inlet manifold bolt (E)	M6 x 1.0 x 10	46-53	34-39
Turbocharger mount cover	M10 x 1.50 x 25	46-53	34-39

(E) = Exception To Standard.

SERVICE TOOLS

TOOL NAME	TOOL NO.
Turbocharger	
Dial indicator	J 8001-3
Magnetic base indicator set	J 7872
Snap ring pliers	J 28507

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

The engine lubrication system includes an oil intake screen and tube assembly, an oil pump, an oil pressure regulator valve, full flow oil filters with a bypass valve, an oil cooler and oil cooler bypass valve (Fig. 1).

A rotor type oil pump is located in a recess at the lower front of the cylinder block. The oil pump gear is driven by the camshaft gear.

Oil enters the pump through a screened inlet located near the bottom of the oil pan. The pressurized oil from the pump passes through the oil filter located on the right front side of the cylinder block. The oil filter adaptor has a bypass valve which, in the event of filter restriction, will open at 103 kPa (15 psi). Engine oil is then directed to the oil cooler and then to the engine oil galleries. A bypass valve in the filter base allows continous oil flow to the engine in case of cooler

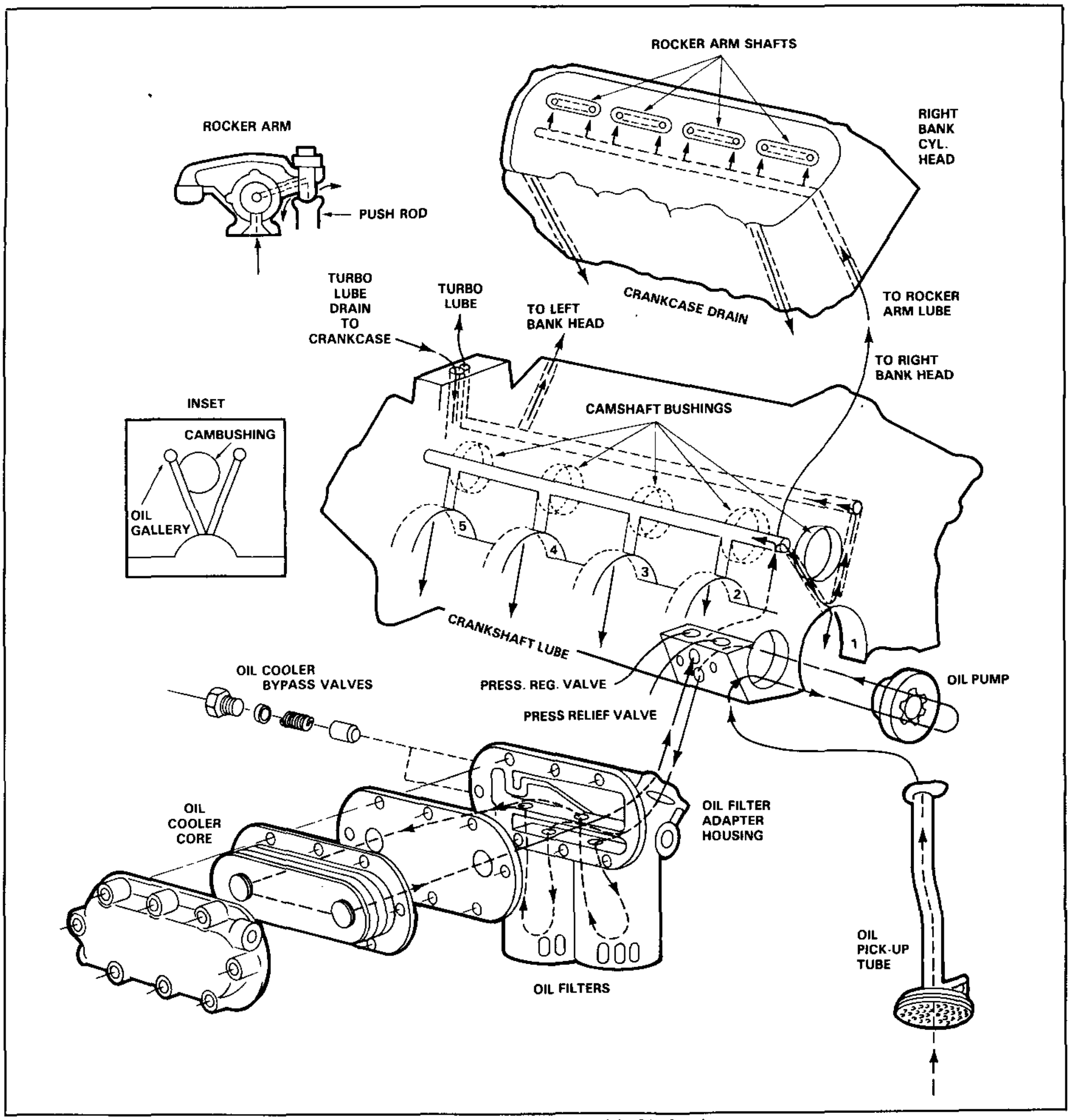


Fig. 1 - Lubrication System with Oil Cooler

restrictions. This bypass valve opens at about 103 kPa (15 psi). Oil then enters the main oil gallery where it is distributed to the five main bearings. The five camshaft bearings are lubricated from vertical passages intersecting the main bearing oil passages. At the front main bearing a third passage connects the right main oil gallery to the left gallery which then feeds the left bank of rocker arms and the turbocharger. Marine turbochargers are supplied lubrication by an external oil line from the left bank cylinder head.

A drilled oil passage at the front of the right bank and at the rear of the left bank cylinder head is supplied with oil from the bores located at respective ends of the cylinder block.

The connecting rod bearings are oiled by constant oil flow from passages drilled through the crankshaft connecting the main journals to the rod journals. A groove around each upper main bearing half furnishes oil to the drilled crankshaft passages.

Oil returns to the oil pan reservoir from the rocker arms through passages at each end of the cylinder heads. Oil from the push rod compartment returns through clearance holes in the lower portion of the compartment near the camshaft. The gear train compartment drains directly into the oil pan.

The crankcase capacity is 9.5 liters (10 quarts).

LUBRICATING OIL PUMP

The lubricating oil pump assembled in a recess at the front of the cylinder block is of the rotor type in which the inner rotor is driven by the outer gear. The outer rotor gear is driven by the camshaft gear. Only one lobe of the inner rotor is in full engagement with the cavity of the outer rotor at any given time, so the former can revolve inside the latter without interference.

Operation

As the rotors revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the oil pan, through the oil pump inlet pipe and a passage in the cylinder block into the rotor compartment of the pump. Oil drawn into the the cavities between the inner and outer rotors on the inlet side of the pump is then forced out under pressure through the discharge port into a passage in the cylinder block which leads to the lubricating oil filter and cooler, (if used) and is then distributed throughout the engine.

If a check of the lubrication system indicates improper operation of the oil pump, remove and disassemble it as outlined below.

Remove Oil Pump

1. Drain the coolant from the engine.

2. Loosen and remove the fan drive and other belts.

3. Remove the fan and fan hub pulley from the water pump drive hub.

4. Disconnect the water hose at the thermostat housing and the other water hoses.

5. Remove the water pump assembly attaching bolts and lift the pump from the front cover. Clean any gasket material from the pump body and front cover.

6. Remove the crankshaft pulley retaining bolt and washer. Refer to Sec. 1.3.7. Use crankshaft pulley removing tool J 29025-A and pull the pulley from the front end of the crankshaft.

7. Remove the front engine mount.

NOTE: If the removal of the oil pump becomes necessary while the engine is in the vehicle, the front of the engine must be supported in order to perform this operation. Loosen the oil pan bolts to facilitate removal of the front cover.

8. Remove the front cover mounting bolts. Lift the cover off the dowels in the front end of the cylinder block leaving the gear train exposed. Clean any gasket material from the cylinder block and the front cover.

9. Loosen and remove the oil pump cover retaining bolt and cover. Remove the outer rotor gear. Then remove the inner rotor and hub.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

The greatest amount of wear in the oil pump is imposed on the lobes of the inner and outer rotors.

This wear may be kept to a minimum by using clean oil. If dirt and sludge are allowed to accumulate in the lubricating system, excessive rotor wear may occur in a comparatively short period of time.

Inspect the lobes and faces of the pump rotors and the pump bushing in the cylinder block for scratches or burrs. Scratches or score marks may be removed with a fine stone.

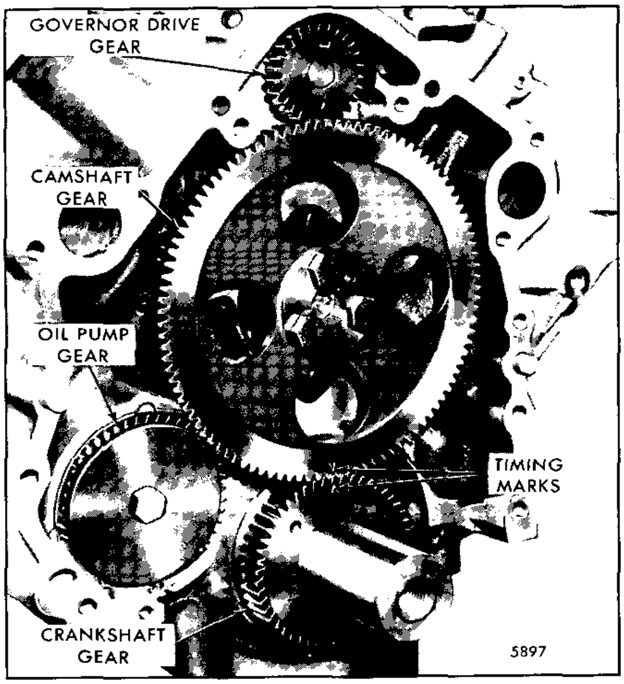


Fig. 1 - Lubricating Oil Pump Mounting

Measure the clearance between the inner and outer rotors at each lobe. The clearance should not be less than .05 mm (.002") or more than .15 mm (.006").

Inspect the teeth on the outer rotor gear for chipped or worn teeth. If the teeth are excessively worn, replace the parts. The rotors are serviced as matched sets, therefore, if one rotor needs replacing, replace both rotors. Refer to Section 4.0 for replacing and machining the oil pump bushing.

Assemble Oil Pump In Block

After the oil pump parts have been cleaned and inspected refer to Fig. 1 and assemble the oil pump in the cylinder block as follows:

1. Lubricate the oil pump outer rotor with engine oil and place it in the cylinder block.

2. Lubricate the oil pump inner rotor with engine oil and place it on the hub.

3. Install the inner rotor and hub with the smaller diameter end of hub into the outer rotor. Seat the small diameter in the bolt hole counter-bore.

4. Install the cover and bolt over the pump and tighten the bolt to 58-66 Nm (43-49 lb-ft) torque.

5. Rotate the gear (7) full turns to insure freeness of the pump after installation. Oil pump gear backlash should be 0.076-0.152 mm (0.003-0.006") new or 0.229 mm (0.009") maximum.

6. Refer to Section 1.3.5 and install the front engine cover.

7. Install the water pump assembly.

8. Install the front engine mount.

9. Install the pulley on the end of the crankshaft.

10. Install the fan hub pulley and fan on the water pump drive hub.

11. Install the fan pulley and other drive belts. Use belt tension gage J 23600-B to adjust the belt tension.

LUBRICATING OIL PRESSURE REGULATOR AND RELIEF VALVES

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve installed in the cylinder block at the right front (Fig. 1).

The oil pressure regulator consists of a hollow piston-type valve, a spring, gasket and plug. The valve is located in an oil gallery in the cylinder block and is held tight against a counter-bored valve seat by the valve spring and plug. When the oil pressure exceeds 483 kPa (70 psi) the valve is forced from its seat and the lubricating oil is by-passed to the oil pump inlet.

Under normal conditions, the pressure regulator valve should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure. Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator Valve

1. Remove the plug and washer from the cylinder block at the right front side of the block.

2. Withdraw the spring and the valve from the valve bore in the cylinder block.

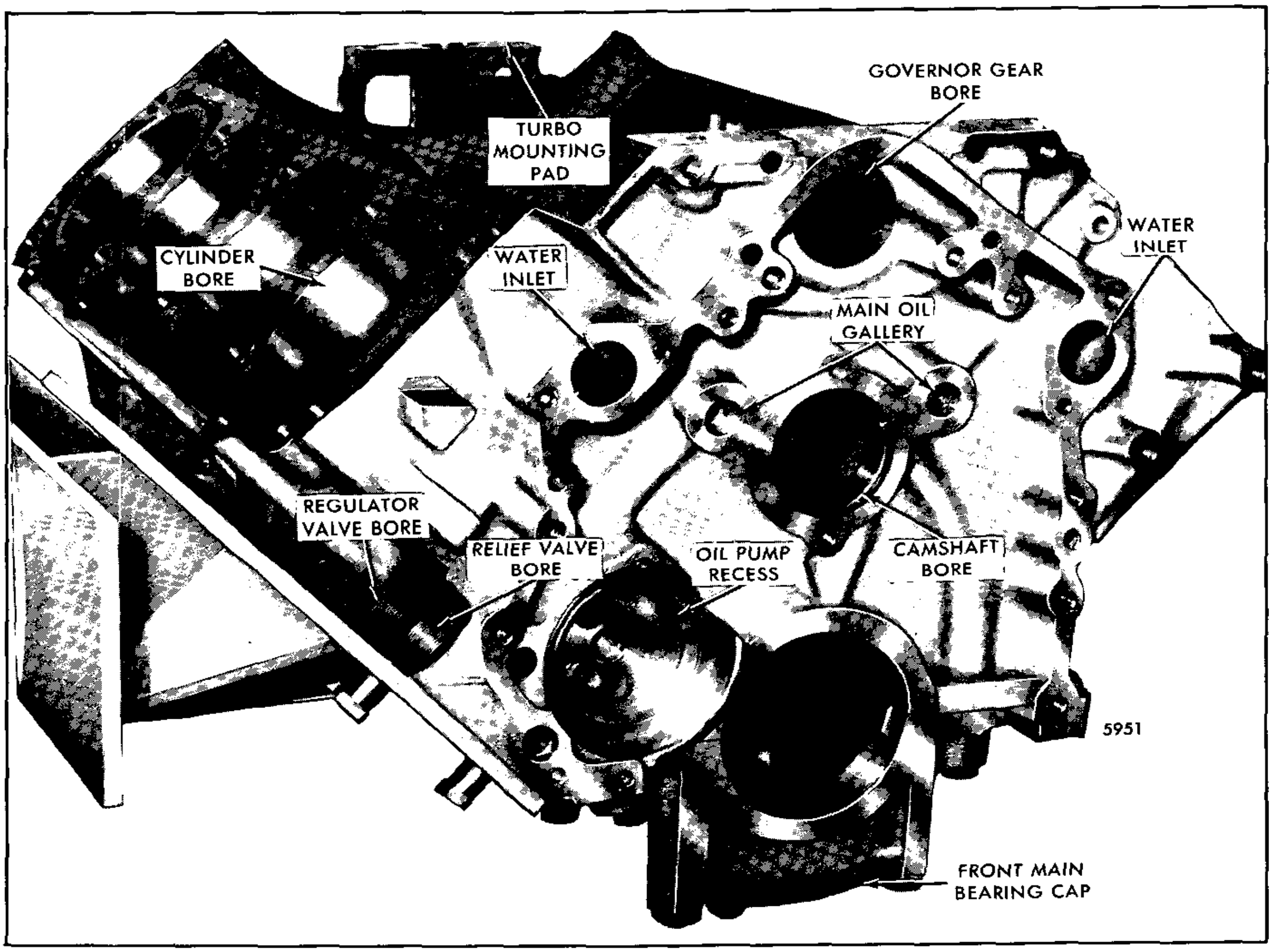


Fig. 1 - Location of Oil Pressure Regulator and Relief Valve Bores

Inspection

Clean all of the components in fuel oil and dry them with compressed air. Then inspect the parts for wear or damage.

The regulator valve must move freely in the valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be be replaced.

Replace a fractured or pitted spring.

Use valve spring tester J-22738-02 to check the spring load of the regulator and relief valve springs. Replace a spring if a load of less than 289.13N (65 lbs.) will compress the spring to 50.8 mm (2.0").

Install Oil Pressure Regulator Valve

1. Apply clean engine oil to the outer surface of the valve and slide it into the valve bore in the block at the right front side, closed end first.

> **NOTE:** The pressure regulator and relief valves and springs are interchangeable with each other.

2. Install a new gasket on the plug.

3. Insert the spring in the valve.

4. While compressing the spring, start the (1-1/4"-16) plug, in the block, then tighten the plug to 130-145 Nm (96-107 lb-ft) torque.

Oil Pressure Relief Valve

Oil leaving the pump under pressure passes into the pressure relief valve. The spring-loaded valve opens when the pressure exceeds approximately 662 kPa (96 psi) and directs the excess oil to the oil pan. The pressure relief valve is located next to the oil pressure regulator valve at the right front of the cylinder block.

The pressure relief valve consists of a hollow piston-type valve, a spring and a nut and washer to retain the valve.

Service operations for the pressure relief valve are similar to those of the regulator valve.

LUBRICATING OIL FILTERS

Full-flow type lubricating oil filters are used on the engine (Figs. 1 and 2). The oil filters are mounted in a downward position. The filters are of the throw away spin on type.

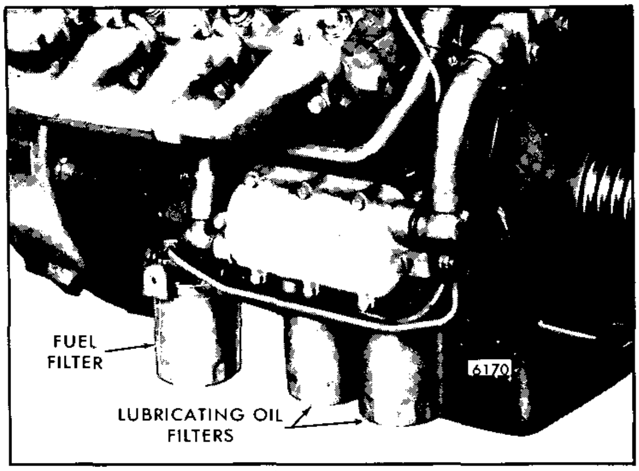


Fig. 1 - Spin-On Oil Filter

All of the oil supplied to the engine by the oil pump passes through the filters before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor and into the elements. Impurities are filtered out as the oil is forced through the elements and out through another passage in the filter adaptor.

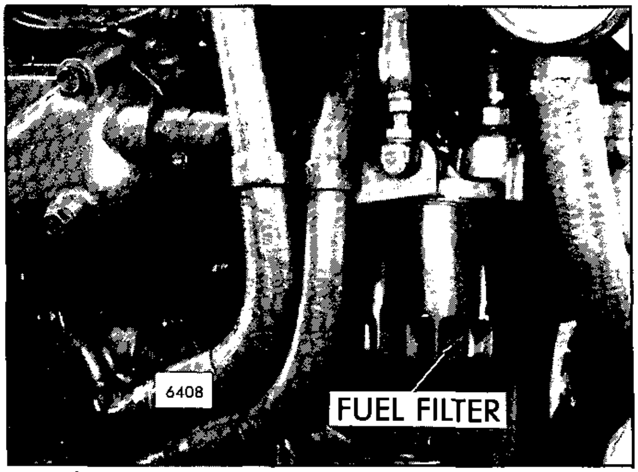


Fig. 2 - Marine Mounting of Spin-On Oil Filter

A bypass valve in the filter adaptor which opens at approximately 103 kPa (15 psi) will bypass the oil should the filters become clogged.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action.

Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found in the filters at time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filters at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

Replace Spin-On Oil Filter

Replace the full-flow oil filters as follows:

1. Use oil filter wrench J 22775 and remove the oil filters.
2. Discard the used oil filters.
3. Clean the filter adaptor or base with a clean lint free cloth.
4. Lightly coat the oil filter seal with clean engine oil.
5. Start a new filter on the adaptor and tighten by hand until seal touches the filter head. Tighten an additional one turn after contact.

NOTICE: Mechanical tightening will distort or crack the adaptor.

6. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately ten (10) minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

LUBRICATING OIL COOLER

Oil coolers are provided for some engines Figs. 1 and 2. Normally, a naturally aspirated engine does not require an oil cooler, but can be used if desired. The oil cooler or filter adaptor is mounted on the lower right front side of the cylinder block.

To assure engine lubrication, should the oil cooler become plugged, a bypass valve bypasses oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The bypass valve opens at approximately 103 kPa (15 psi). The valve components are the same as and serviced in the same manner as the oil pressure regulator valve in Section 4.1.1.

Cooling water circulated through the oil cooler completely surrounds the oil cooler core. Therefore, whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full flow oil filter, which is also mounted on the oil cooler adaptor

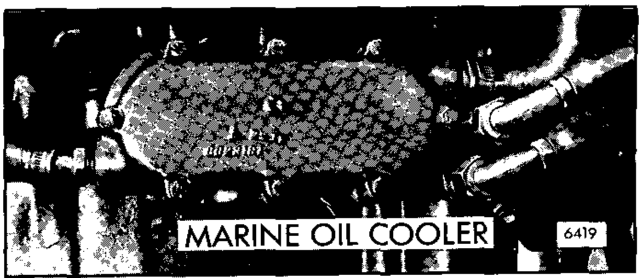


Fig. 2 - Typical Marine Engine Oil Cooler

(except on marine engines) and then through the oil cooler core and the cylinder block oil galleries.

Remove Oil Cooler Core and Adaptor

1. Drain the cooling system by removing the plug at the bottom of the oil cooler cover.
2. Remove any accessories or other equipment necessary to provide access to the cooler.
3. Disconnect one water hose at the front and one hose at the rear end of the oil cooler cover.

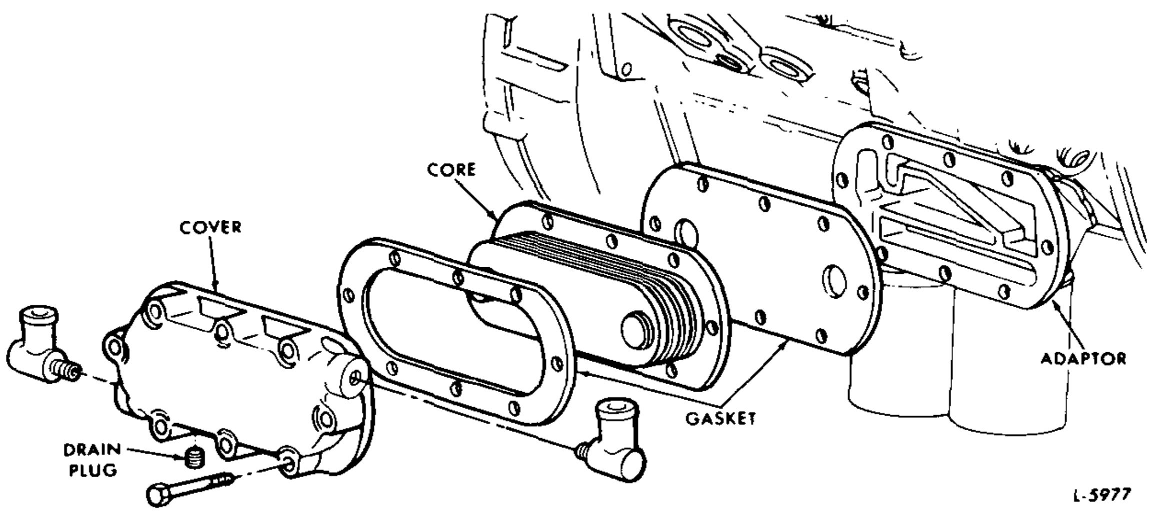


Fig. 1 - Typical Engine Oil Cooler (Except Marine)

4. Matchmark the end of the oil cooler cover, cooler core and adaptor with a punch or file so they can be reinstalled in the same position.
5. Remove the bolts which attach the cover and core to the filter adaptor.
6. If the adaptor is to be removed, the oil filters must first be removed. Marine oil coolers have remote filters and require that the lubrication lines be disconnected before removing the adaptor (Fig. 3). Then, remove the bolts which attach the adaptor to the cylinder block. Withdraw the adaptor and seal rings.

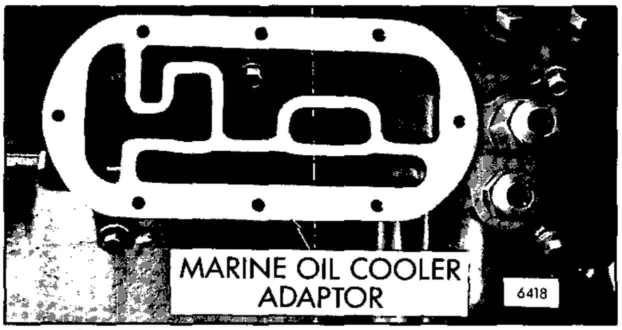


Fig. 3 Marine Engine Oil Cooler Adaptor (Lube Lines Disconnected)

7. Remove all traces of gasket material from the oil cooler components.

Clean Oil Cooler Core

1. *Clean oil side of core* - Remove the core from the oil cooler. Circulate a solution of 1,1,1 tricholorethane through the core passages with a force pump to remove the carbon and sludge.

CAUTION: To avoid personal injury, perform this operation in the open or in a well ventilated area. Avoid breathing the fumes or direct contact of the chemicals with your skin. Use recommended safety equipment as required.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate a cleaning alkaline solution through the core and flush thoroughly with clean, hot water.

2. Clean water side of cooler - After cleaning the oil side of the core, immerse it in the following solution: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming.

Watch the process carefully and when bubbling stops (this usually takes from 30 to 60 seconds) remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

NOTICE: Do not attempt to clean an oil cooler core when an engine failure occures in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

PRESSURE CHECK OIL COOLER CORE

After the oil cooler core has been cleaned, check for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal. Drill and tap the plate prior to mounting to permit an air hose fitting to be attached at the inlet side of the core (Fig. 4).

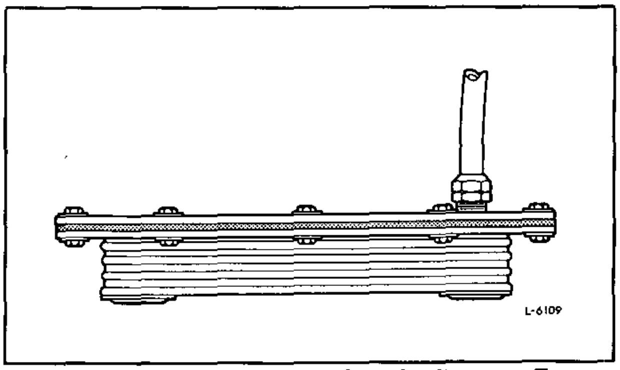


Fig. 4 - Preparing Oil Cooler Core for Pressure Test

2. Attach an air hose, apply approximately 517-1 034 kPa (75-150 psi) air pressure and submerge the oil cooler and plate assembly in a container of water heated to 82°C (180°F). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

CAUTION: When making this pressure test be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.

3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

NOTICE: In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent serious damage.

Install Oil Cooler Core

1. If the oil cooler adaptor was removed from the cylinder block, check to make sure the mounting face is clean.

2. Install new seal "O" rings in the counter-bores in the adaptor and place it against the cylinder block.
3. Secure the adaptor to the cylinder block with four bolts. Tighten the bolts to 46-53 N·m (34-39 lb-ft) torque.
4. Clean both faces of the core flange of gasket material.
5. Install new gaskets on both faces of the core. Align the matchmarks previously placed on the core and cover and install the assembly on the adaptor.
6. Then, secure the housing in place with eight bolts. Tighten the bolts to 23-27 N·m (17-20 lb-ft) torque. Install the 3/4"-1" water elbows in the cover. On marine engines connect the lubrication lines and tighten.
7. Slide the hose and clamps in position between the cylinder block water inlet and the oil cooler. Secure the clamps in place.
8. Position the hose and clamps in place between the cylinder head outlet elbow and the oil cooler at the front. Secure the clamps in place.
9. Install all of the accessories or equipment it was necessary to remove.
10. Install new oil filters.
11. Make sure the drain plug in the bottom of the oil cooler cover is in place and tighten. Then, fill the cooling and lubricating system to the correct level.

OIL LEVEL DIPSTICK

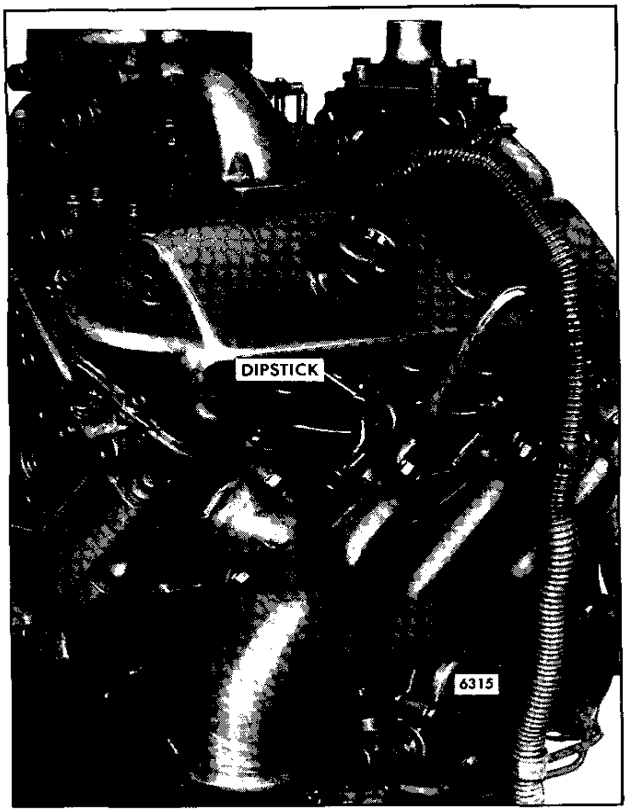


Fig. 1 - Oil Dipstick Mounting

A spring steel type oil level gage is mounted in a tube (Fig. 1) which is pressed in the cylinder head on either the left or right bank. Use a suitable sealer and install a plug in the dipstick hole in the opposite head.

> **NOTE:** Dipsticks for the right or left side of the engine are different lengths and should not be interchanged.

Maintain the oil level between the full and low marks (The distance between the low and full marks is equal to 2 quarts) on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aeration of the oil. Operation below the low mark will expose the pump pick-up causing aeration and/or loss of pressure.

The Fuel Pincher engine crankcase capacity is 9.5 liters (10 quarts). The best time to check the oil level is before operating the engine or as the last step in a fuel stop. This will allow the oil accumulation in the engine to drain back in the crankcase. To check the level, remove the oil gage rod (dipstick), wipe it clean and reinsert it firmly for an accurate reading.

Dipsticks are normally marked for use only when the engine is on a level surface. Improper oil levels can result if the oil level is checked with the engine on a grade.

Fill the crankcase with oil as follows:

1. Fill the oil pan to the full mark on the dipstick.

2. Start and run the engine for approximately ten minutes.

3. Stop the engine and wait a minimum of ten minutes. Then add the required amount of oil to reach the full mark on the dipstick.

Oil Change

1. When oil is drained via the oil pan drain plug and the oil filters are not disturbed, then 9.5 liters (10 quarts) of oil will be required.

2. If only the filters are replaced then 1.9 liters (2 quarts) should be added providing the oil level was full at start.

3. A normal lube oil change will require 11.4 liters (12 quarts) of oil and 2 new filters.

It is recommended that, following an oil change, the engine should be running to verify oil pressure and to check for oil leaks. Correct as necessary any abnormal conditions. Stop the engine and allow approximately 10 minutes for the oil from the various parts of the engine to drain back to the crankcase. Check the oil level to be sure that it is at proper level on the dipstick. Add oil if necessary.

OIL PAN

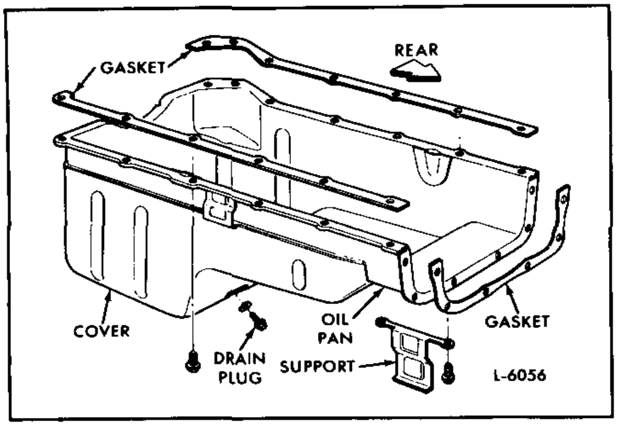


Fig. 1 - Former Oil Pan Assembly

The former oil pan and cover assembly Fig. 1 used on the engine is a stamped steel pan and cover which requires a three-piece gasket. Two oil pan cover retainers are also used to prevent the outer pan cover from falling off if the remote possibility of a bonding failure should occur. The retainers should not contact the oil pan cover when assembled.

The new oil pan assembly (Fig. 2) used on the engine is a stamped steel pan. A one piece pan-to-block reusable isolator seal is used along with a one piece gasket, an oil pan rear seal adaptor and a left and right bank rail reinforcement.

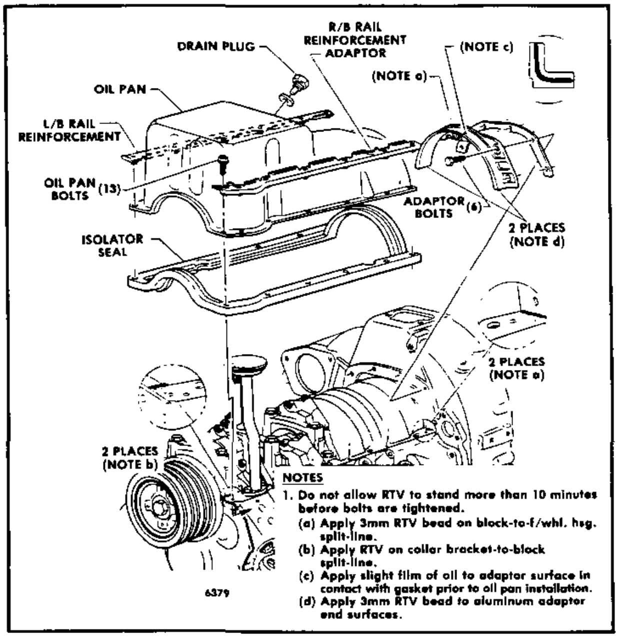


Fig. 2 - Current Oil Pan Assembly

Removing and Installing Oil Pan

On some engine applications it may be possible to remove the oil pan without removing the engine. If the engine is to be removed from the vehicle, the oil pan should be left in place until the engine is removed.

The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary. However, the following will generally apply.

1. Remove the drain plug and drain the oil.

2. Detach the oil pan and on the new pan the rear seal adaptor; taking care not to damage the oil pump inlet pipe and screen.

3. Remove the oil pan gaskets completely. The new pan has an isolator seal that is reusable and must be removed carefully to avoid damage.

4. Clean all of the old gasket material from the cylinder block, seal adaptor, flywheel housing and the oil pan. Clean the oil pan with a suitable solvent and dry it with compressed air.

5. Check a stamped oil pan and cover for dents or breaks in the metal which may necessitate repair or replacement. Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface.

Install Oil Pan

1. When replacing the former oil pan assembly, use new gaskets. When replacing the new pan assembly the isolator seal is reusable and must be inspected for damage before installing. However, the adaptor to flywheel gasket must be replaced.

Apply Room Temperature Vulcanizer (RTV) sealer at two places on the block-to-flywheel housing split line. Also, two places at the front of the block on the collar bracket-to-block split line.

2. Install adaptor to the flywheel housing and torque the bolts to 10-15 Nm (7-11 lb-ft) on the new pan.

3. With the drain plug removed install the oil pan assembly in position on the block. Install and finger tighten several bolts. On the new pan install the bolts through the left and right bank rail reinforcements to the pan, position on the block and finger tighten several bolts.

4. Place left bank pan cover retainer one bolt hole forward of the right bank retainer (former pan). Install all the remaining pan bolts and tighten them to 10-12 Nm (8-9 lb-ft) torque (former); 10-15 Nm (7-11 lb-ft) torque (new).

5. Install and tighten the 1/2"-20 oil drain plug. Tighten the plug (with copper washer) to 24-34 Nm (18-25 lb-ft) torque.

6. Fill the oil pan with new oil to the full mark on the dipstick. Then, start and run the engine for ten minutes and check for oil leaks.

7. Stop the engine and, after approximately ten minutes, check the oil level. Add oil, if necessary.

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air past the piston rings. This air sweeps up through the engine and passes through a crankcase breather located in the cylinder block valley cover and then exits to the atmosphere via a draft tube.

The crankcase breather has a hose connection between the breather and the draft tube.

Service

It is recommended that the hose be inspected and cleaned, if necessary, to eliminate the possibility of clogging. This can best be done by removing the hose and cleaning it.

The wire mesh (element) in the breather assembly should be cleaned if excessive crankcase pressure is observed, or at time of overhaul.

If it is necessary to clean the element, remove the breather from the valley cover. Wash the breather assembly in fuel oil and dry it with compressed air.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

OIL PUMP REWORK

The following procedure provides in detail, the steps required to remove, replace and machine the standard size and/or oversize oil pump bushings.

These instructions are for a horizontal milling machine. The procedure for machining the oil pump bushing using a vertical milling machine is the same except for the initial setup of the block on the mill table.

1. Remove the damaged oil pump bushing from the block using J 23907-1 slide hammer and J 29140-2 puller.

2. If on inspection, the oil pump cavity (Reference "S", Fig. 1), is found to be greater than 79.438mm (3.1275") due to wear or a bushing spinning, it will be necessary to machine the cavity to accept an oversize bushing. The oil pump cavity must be checked for cracks after being machined oversize. If an oversize bushing is required, the oil pump cavity should be machined to the following specifications prior to installing the oversize bushing. For the 0.254 mm (0.010") O/S bushing, machine the cavity to 79.654-79.692 mm (3.1360-3.1375"). For the 0.508 mm (0.020") O/S bushing, machine the cavity to 79.908-79.946 mm (3.1460-3.1475"). The surface finish is 4.0 micrometers (160 microinches).

3. Install a new bushing flush to .13 mm (.005") below the surface using J 8092 driver and J 29140-1 installer. The split line of the bushing must be towards the top of the block and the locating notch at 110° from vertical towards the centerline of the block (see Fig. 1).

4. Secure the block on the table of the mill with the oil pan rail down and the oil pump pocket facing the spindle.

5. Using an .0025 mm (0.0001") dial indicator, check surface "E" (see Fig. 1); it must be square to within .025 mm (0.001"). Shim or realign the block to achieve this reading.

6. Using the same dial indicator, dial indicate the pilot hole on surface "D" (see view "C"). Adjust the machine for a maximum of .0125 mm (.0005") T.I.R. runout on the pilot hole.

7. Place masking tape over the two oil pump cavities and the tapped center hole to prevent machining debris from entering the block.

8. The center of the pilot hole has now been established; move the tool horizontally towards the vertical centerline of the block 3.810 mm (0.1500") plus or minus .04 mm (0.0016"). The centerline of the oil pump bushing is now established.

9. When the correct bushing has been installed, bore out the inside diameter of the bushing to 76.20-76.23 mm (3.000-3.0012"). The surface finish is 0.8 micrometers (32 microinches).

10. Using compressed air, remove all loose machining debris from the cylinder block.

11. Remove the masking tape from the oil pump cavities and thoroughly clean the cylinder block by immersing it in an agitated cleaning tank.

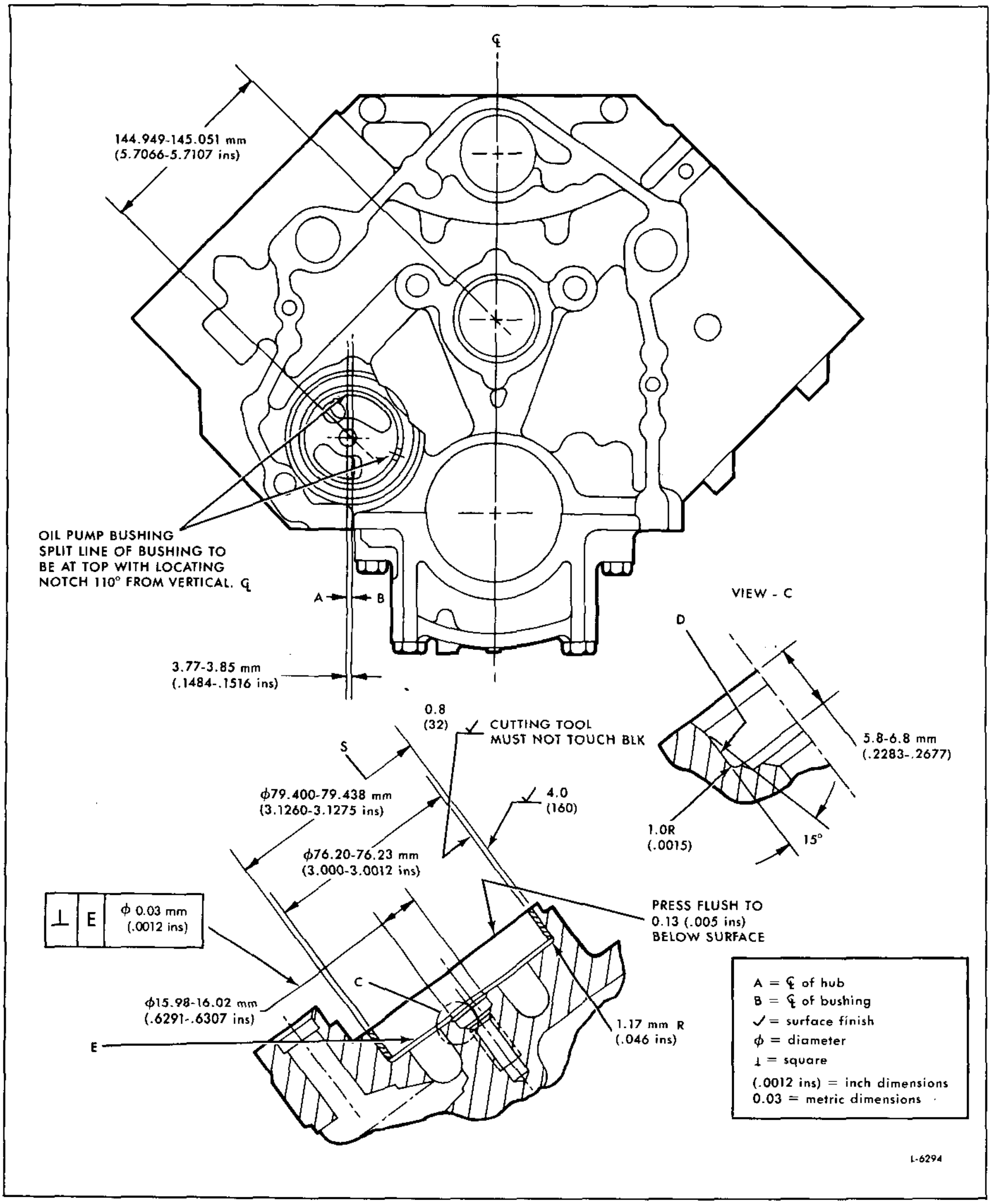
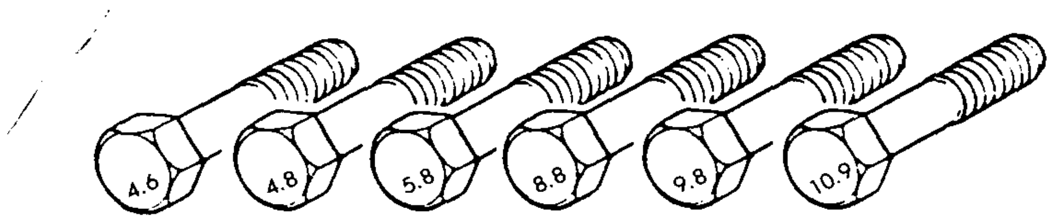


Fig. - 1 Oil Pump Bushing Installation

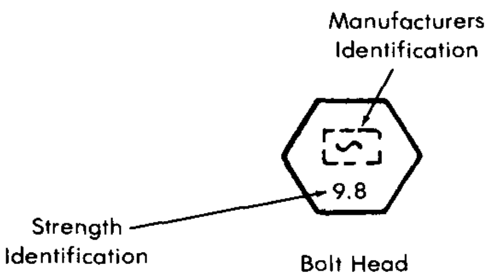
STANDARD METRIC BOLT AND NUT TORQUE SPECIFICATIONS

Thread Size Diameter × MM Per Thread	BOLT CLASSES / TORQUES		
	8.8	9.8	10.9
	Nm/LB-FT	Nm/LB-FT	Nm/LB-FT
M5 × .8	None used	5.0-6.0/3.7-4.4	7.0-8.0/5.2-5.9
M6 × 1.0	" "	10-12/7.4-9.0	13-15/10-11
M8 × 1.25	" "	23-27/17-20	30-34/22-25
M10 × 1.50	" "	46-53/34-39	58-66/43-49
M12 × 1.75	" "	79-91/58-67	101-116/74-86
M14 × 2.0	" "	126-144/93-106	160-184/118-136
M16 × 2.0	" "	192-220/142-162	245-280/181-207
M20 × 2.5	334-384/246-283	None used	478-550/353-406

STANDARD METRIC BOLTS



Metric Bolts — Identification class numbers correspond to bolt strength — Increasing numbers represent increasing strength.



Bolt Head

BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (Nm)	TORQUE (lb-ft)
Oil cooler housing bolts	M8 x 1.25 x 65	23-27	17-20
Oil pan bolts (E)	M8 x 1.25 x 30	10-12	8-9
Oil cooler adaptor bolts	M10 x 1.50 x 40	46-53	34-39
Oil pump cover bolt	M10 x 1.50 x 55	58-66	43-49
Oil drain plug (E)	1/2" x 20	24-34	18-25
Oil pressure regulator plug (E)	1-1/4"-16	130-145	96-107

(E) = Exceptions To Standard.

SERVICE TOOLS

TOOL NAME	TOOL NO.
Oil Pump	
Belt tension gage	J 23600-B
Crankshaft pulley removing tool	J 29025
Oil filter wrench	J 22775

SECTION 5

COOLING SYSTEM

CONTENTS

COOLING SYSTEM

Radiator and Fan Cooling

The engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler (if used) and into the cylinder block (Fig. 1).

From the cylinder block, the coolant passes up through the cylinder heads and, when the engine is at normal operating temperature, through the thermostat housing and into the upper portion of the radiator. Then, the coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat housing and a bypass provides water circulation within the engine during the warm-up period.

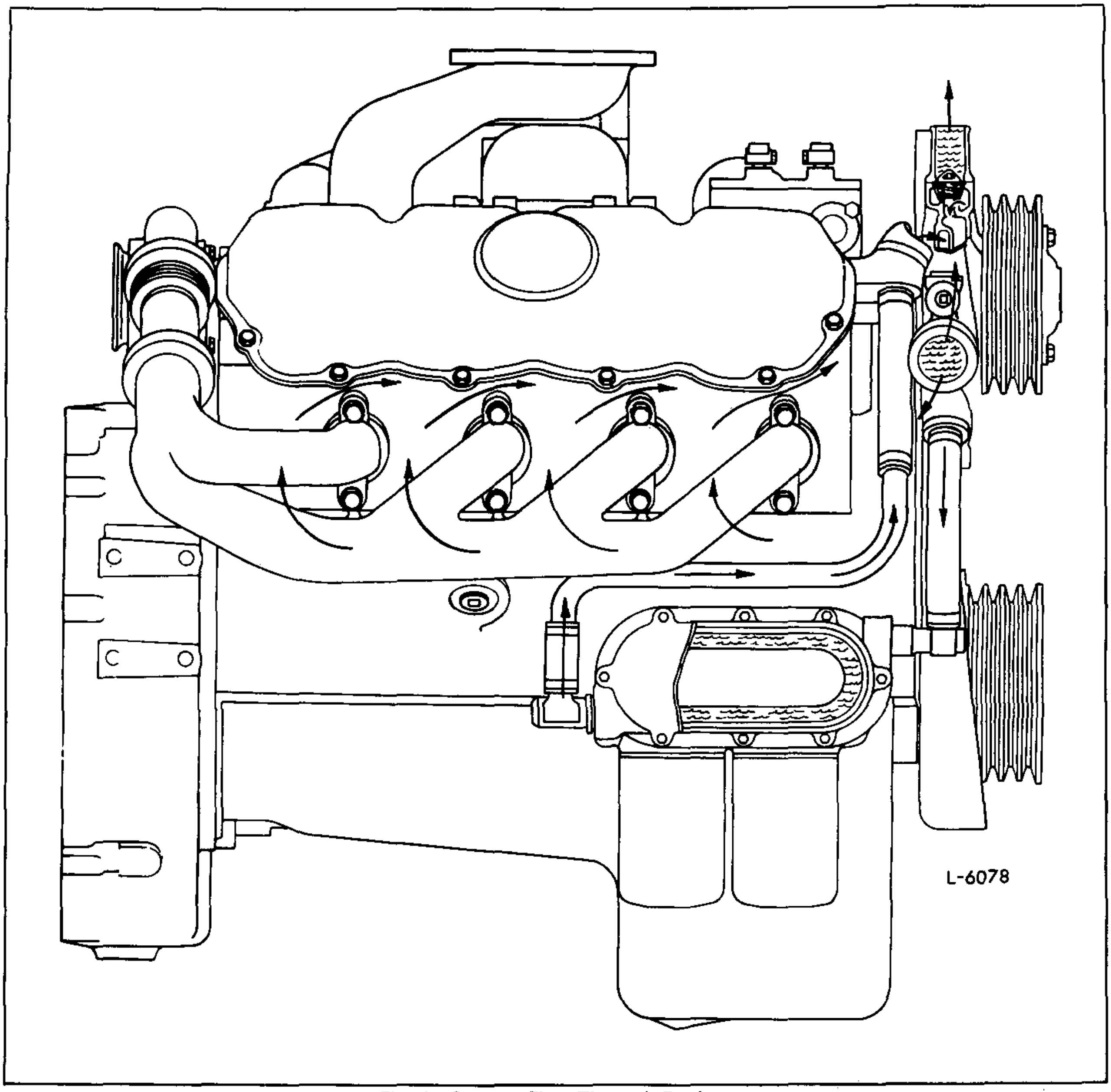


Fig. 1 - Coolant Flow Through Engine

Heat Exchanger Cooling System

In the heat exchanger cooling system, the coolant is drawn by the engine water pump from the heat exchanger and is forced through the engine oil cooler, cylinder block, cylinder heads, exhaust manifolds and turbocharger to the thermostat housings. A bypass from the thermostat housings to exhaust manifolds to the inlet side of the water pump permits circulation of coolant through the engine when the thermostats are closed. When the thermostats are open, the coolant flows through the heat exchanger where it is cooled.

An engine driven raw water pump circulates the raw water (sea water) through the heat exchanger to lower the temperature of the engine coolant.

COOLING SYSTEM MAINTENANCE

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as the valves and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant when oil to water oil coolers are used. Refer to Section 13.3 for coolant recommendations.

Cooling System Capacity

The capacity of the basic engine cooling system cylinder block, head, thermostat housing and oil cooler housing (if used) is 11.9 Liters (12.5 quarts).

To obtain the complete amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of the radiator and related equipment should be obtained from the equipment supplier, or the capacity of the particular cooling system may be determined by filling the system with water, then draining and measuring the amount required.

Fill Cooling System

Before starting the engine install and tighten any drain plugs that were removed and fill the cooling system with water. The use of clean, soft water will eliminate the need for descaling solutions to clean the cooling system. A hard mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale. Refer to *Coolant Specifications* in Section 13.3.

Start the engine and after normal operating temperature has been reached, allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within two inches of the filler neck.

Should a daily loss of coolant be observed and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head gasket into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate this leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the water outlet line.

Drain Cooling System

Refer to Fig. 2 and drain the cooling system by removing the 3/4" pipe plug from the cylinder block located in both banks. Also, remove the 3/8"-18 pipe plug from the bottom of the oil cooler cover.

NOTICE: Some engines may have an immersion type coolant heater installed in the cylinder block 3/4" drain hole. Refer to cold weather starting in Section 12.6

Removal of the radiator filler cap permits air to enter the coolant passages and the coolant to drain completely from the system. If freezing weather is anticipated and the engine is not protected by antifreeze, drain the cooling system completely when the engine is not in use. Leave the drain plugs out until the cooling system is refilled. Should any entrapped water in the cylinder block, radiator or other engine parts freeze, it will expand and may result in damage to the engine.

Flushing

Flush the cooling system each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, cleaning the system, for the next solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the engine.
2. Refill with soft clean water.

   NOTICE: If the engine is hot, fill *slowly* to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.
4. Drain the unit completely.
5. Refill with the solution required for the coming season.

Cooling System Cleaners

If the engine overheats, and the fan belt tension and water level have been found to be satisfactory, clean and flush the entire cooling system. Remove scale formation by using a reputable and safe descaling solvent. Immediately after using the descaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the descaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse flush before filling the system.

Reverse Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse flushed. The water pump should be removed and the radiator and engine reverse flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse flushing is

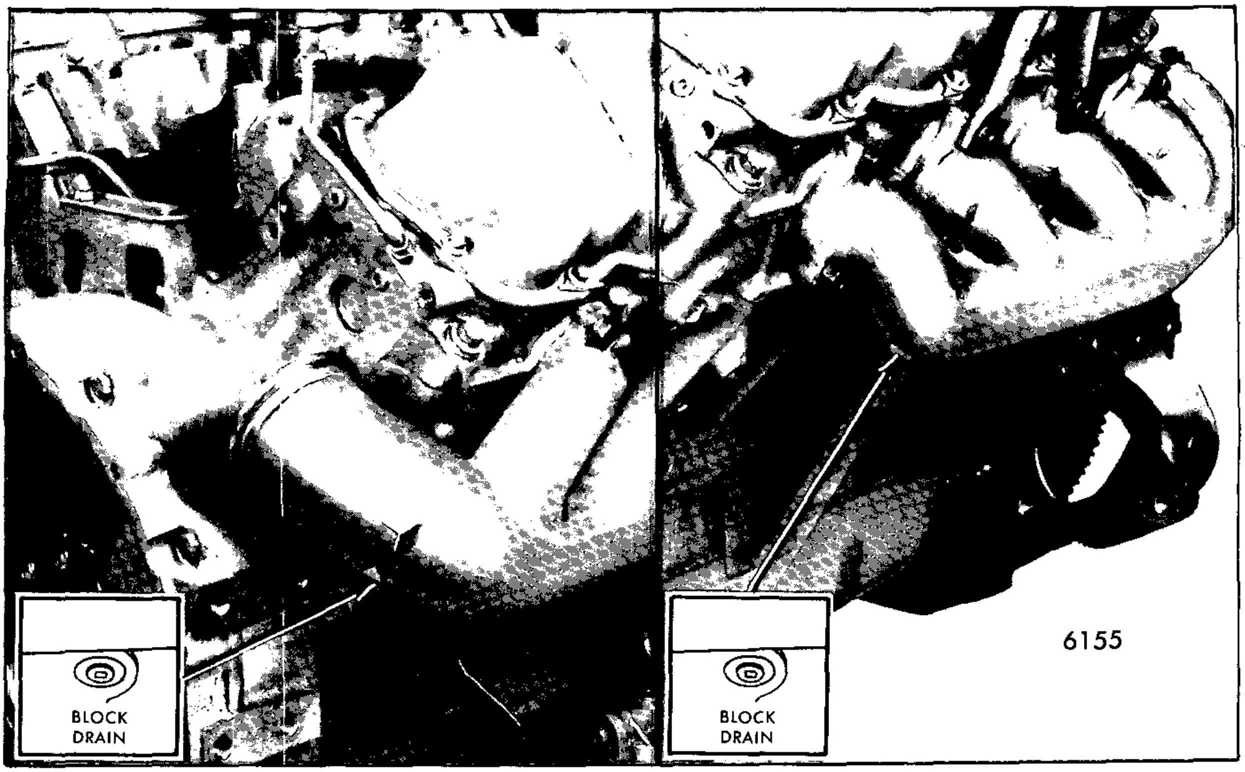


Fig. 2 - Location of Cylinder Block Coolant Drains

accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing deposits out.

The radiator is reverse flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at the top of the radiator to lead water away from the engine.
3. Attach a hose to the bottom of the radiator and insert a flushing gun in the hose.
4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
5. Turn on the water and when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

NOTICE: Apply air gradually. Do not exert more than 138 kPa (20psi) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

the cylinder block and cylinder head water passages are reverse flushed as follows:

1. Remove the thermostats and the water pump.
2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
3. Attach a hose to one of the water outlets at the top of the cylinder block and insert the flushing gun in the hose.
4. Turn on the water and when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected.

The fan belts must be checked and adjusted, if necessary, to provide the proper tension and the fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination, that is damaging to the engine if it is not corrected immediately, is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating, and when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines during the cold season when the cooling system is normally filled with an ethylene glycol antifreeze solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts.

To remove such contaminants from the engine, both the cooling system and the lubrication system must be thoroughly flushed as follows:

Cooling System

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following procedure is recommended.

1. Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to 3.8 Liters (one gallon) of water.
2. Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator.
3. Fill the cooling system with the Calgon solution.
4. Run the engine for five minutes.
5. Drain the cooling system.
6. Repeat Steps 3 through 5.
7. Fill the cooling system with clean water.
8. Let the engine run five minutes.
9. Drain the cooling system completely.
10. Install the engine thermostats.
11. Install and tighten the drain plugs and refill the engine with fresh coolant.

Lubrication System

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using Butyl Cellosolve or equivalent, is recommended.

CAUTION: Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.
2. Remove and replace the spin on oil filters.
3. Mix two parts of Butyl Cellosolve, or equivalent, with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.
4. Start and run the engine at a fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.
5. After the specified time, stop the engine and immediately drain the crankcase. *Sufficient time must be allowed to drain all of the fluid*. Remove and replace the oil filters.
6. Refill the crankcase with SAE 10 oil after the drain plug is replaced and run the engine at the same fast idle for ten (10) or fifteen (15) minutes and again drain the oil thoroughly.
7. Remove and discard the oil filters. Install new spin-on filters.
8. Replace the drain plug and fill the crankcase to the proper level with the oil recommended for normal engine operation.
9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1000 to 1200 rpm) for approximately 30 minutes. Then stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contamination deposits if the starting speed is slow.
10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly. *Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service*.

Coolant Recovery System

The engine cooling system design must be such that a reasonable loss of coolant from the normal full level will not result in aeration of engine coolant The capability of the system to handle the coolant loss is determined by a drawdown test. The minimum drawdown for systems having a total capacity between 40 and 120 quarts (38 and 114 liters) is 10% of the capacity.

If minimum drawdown capacity cannot be obtained and space is not available for an integral top/surge tank or a remote surge tank, the additional capacity may be obtained with a coolant recovery tank. The coolant recovery tank should be mounted as high as the installation permits and must be sized to provide cooling expansion volume (6% of total volume,

including heater and lines) above the added drawdown capacity. The pressure cap used with this system must be of the type that provides a vacuum tight seal on the top of the top/surge tank filler neck.

As the engine temperature increases, the coolant and air in the system starts to expand and build pressure. The valve in the radiator pressure cap unseats and allows the coolant to flow into the coolant recovery tank (Fig. 3).

When the engine starts to cool down, the air and coolant contract causing a void and creating a vacuum in the system. The vacuum unseats another valve in the radiator pressure cap, allowing the coolant to flow back into the expansion tank or radiator (Fig. 4).

Any leak in the cooling system (radiator top tank, pressure cap, hose connection, etc.) will prevent the coolant recovery system from functioning and visual inspection of recovery tank will give a false indication of coolant level. Therefore, a periodic check of the top tank and/or surge tank coolant level under ambient condition is recommended. Under normal operation, a small amount of coolant will be lost due to evaporation. If an abnormal amount of coolant is being used, check the cooling system for leaks. The coolant level in the recovery tank should be checked daily.

The recovery system should have a functional capacity (low cold to full hot) of four quarts minimum (3.8 liters). Should the vehicle cooling system be modified to increase total coolant capacity, such as additional heaters in a school bus, the functional capacity of the coolant recovery system should be reviewed and increased accordingly to ensure that it meets the current published requirements for minimum expansion volume.

The radiator cap should be checked to ensure that the correct cap is being used. It is recommended that a minimum 9 psi (62 kPa) separate pressure relief valve be used for all automotive cooling systems used in conjuntion with Detroit Diesel Allison engines. The maximum allowable pressure is a function of the radiator an/or heater core design.

Partial filling of the cooling system can result in operation with aerated coolant, or an air-bound water pump. Upon any drain and refill operation of the cooling system, make sure that the system is full. Bleed all air from the system, including heater and heater hoses. If a heater shutoff valve exists, the heater must be turned on during the refill operation.

Run the engine until normal operating temperature has been reached (to open thermostats). With the thermostats open, run the engine at 1500 rpm for ten minutes to allow the system to deaerate. Then fill the system and reinstall pressure cap. Fill the coolant recovery bottle to the HOT level mark. Install recovery bottle cap.

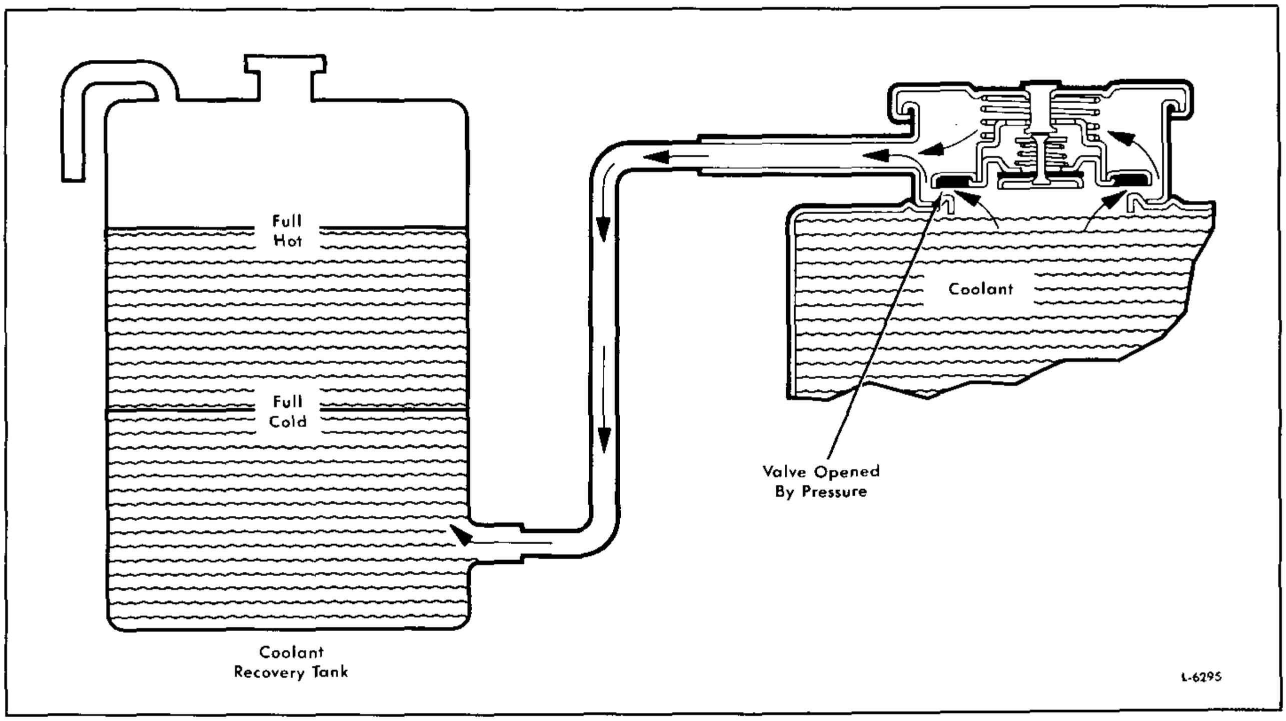


Fig. 3 - Coolant Expansion

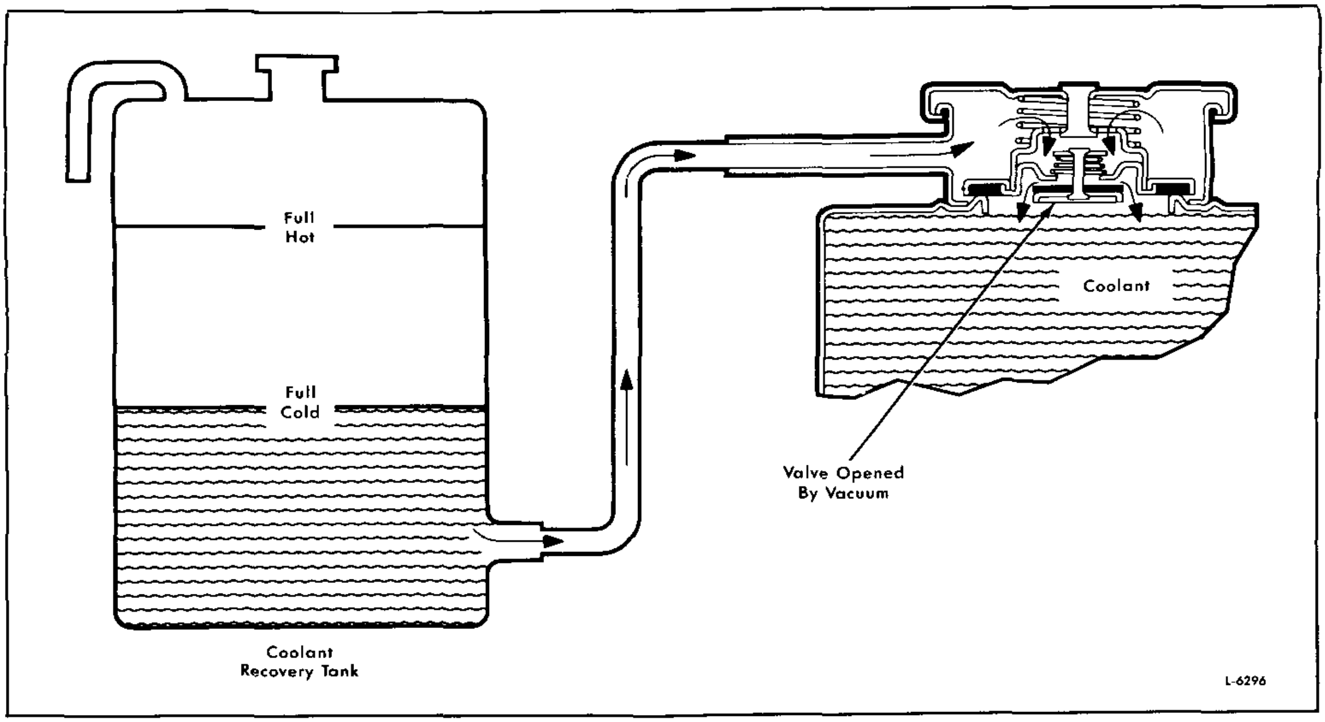


Fig. 4 - Coolant Recovery

WATER PUMP

A centrifugal-type water pump (Fig. 1) is attached to the engine front cover (standard high mount pump shown in Fig. 2). It circulates coolant through the oil cooler, cylinder block, cylinder heads and the radiator or heat exchanger. The pump is belt driven by the crankshaft pulley.

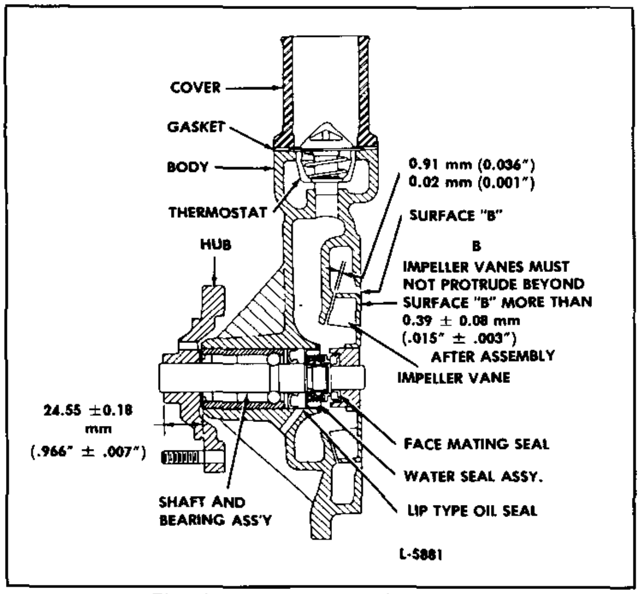


Fig. 1 - Water Pump Assembly

An impeller is pressed onto one end of the water pump shaft and a water pump drive pulley hub is pressed onto the opposite end of the shaft. The shaft is supported by a double row combination roller and ball bearings. The shaft and bearings constitute an assembly and are serviced as such since the shaft serves as the inner race of the combination roller and ball bearings. Coolant is prevented from creeping along the shaft toward the bearings by a water seal assembly. An oil seal is pressed onto the shaft to further prevent the coolant from reaching the bearings.

The sealed water pump shaft/bearing assembly is filled with lubricant when assembled. No further lubrication is required.

This section on the water pump uses the standard high mount water pump as a base. Where there are differences, they will be specifically stated. Depending upon the application, the engine will have one of three water pump configurations.

The standard high mount pump and the standard low mount pump are used in automotive and industrial applications. The marine low mount pump is used in marine applications. The standard low mount pump uses a different body than the standard high mount pump. The body of the standard low mount pump, unlike the standard high mount pump, has an impeller cover, O-ring and snap ring on the back side sealing in the impeller.

Fig. 2 - Water Pump Mounting

The marine low mount pump uses a different body and a different pulley hub than the standard high mount pump. It also incorporates the same impeller cover, O-ring and snap ring as the standard low mount pump. The difference between the marine low mount pump and the standard low mount pump is the body and the pulley hub.

All the water pumps use the same shaft/bearing assembly, oil seal, water seal assembly, face mating seal and impeller.

Remove Water Pump (Automotive)

1. Remove the belts from the water pump pulley.
2. Remove the fan assembly and water pump pulley.
3. Drain the cooling system.
4. Remove the hoses from the water pump.
5. Remove the water pump assembly attaching bolts and remove the water pump from the upper front cover.
6. Remove and discard the gasket. The standard low mount and marine low mount pumps do not require a gasket.

Remove Fresh Water Pump (Marine)

1. Remove all necessary clamps and hoses to remove the heat exchanger.
2. Disconnect and remove the dearation tube.
3. Remove retaining bolts and heat exchanger.

4. Loosen the alternator bolts and remove the drive belts.
5. Remove the fuel line (from filter to L/B cylinder head) clips and bolts.
6. Remove the hose and clamps to the exhaust manifolds (left and right bank) from the water pump.
7. Loosen clamps and position the hose (to water pump from L/B cylinder head water outlet elbow) out of the way.
8. Loosen clamps and position the hose (to water pump from R/B cylinder head water outlet elbow) out of the way.
9. Remove the water pump bolts and remove pump.
10. Remove the bolts and heat exchanger brackets from pump body.
11. Clean gasket material from the water pump body and the front cover.

Replacement of Impeller or Water Seal Assembly

1. Use tool J 29190-A to pull the impeller off the water pump shaft (Fig. 3).

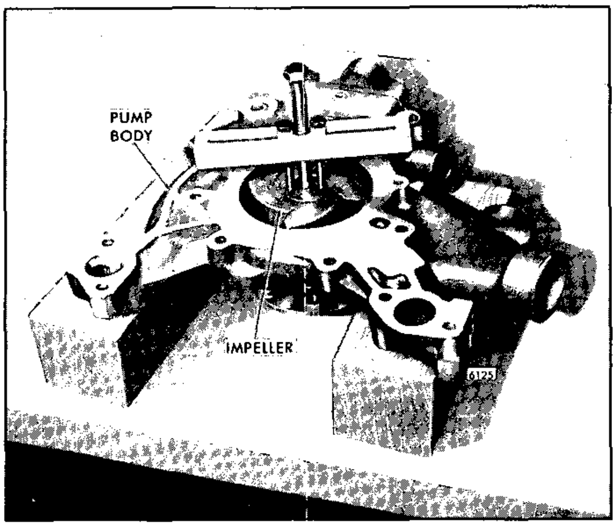


Fig. 3 - Removing Water Pump Impeller Using Tool J 29190-A

2. Remove the face mating seal and pry out the water seal assembly with a screwdriver.

3. Inspect the bearing cavity for scores where the outer perimeter of the water seal assembly seals against the bearing cavity bore. When the bearing cavity bore is scored, a non-hardening sealant should be used in addition to the seal's coating to prevent coolant leakage.

4. Install the water seal assembly and impeller as outlined in Steps 5 through 9 provided in the "Assemble Pump" instructions.

Disassemble Water Pump

1. Using puller tool J 29190-A, remove the pulley hub from the bearing shaft (Fig. 4). For the marine low mount pump use puller tool J 34117 (Fig. 5) or equivalent.

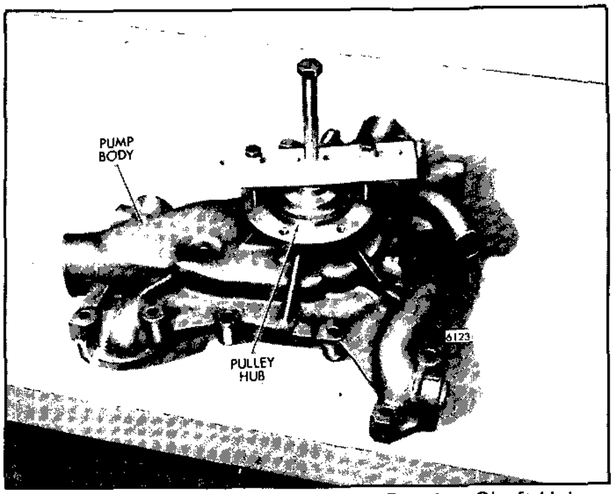


Fig. 4 - Removing Pulley Hub From Bearing Shaft Using Tool J 29190-A

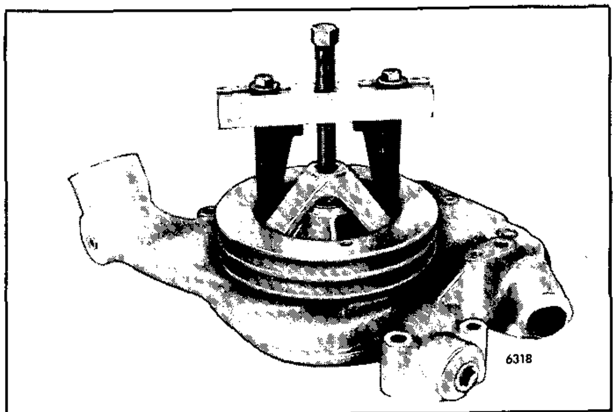


Fig. 5 - Removing Pulley From Bearing Shaft Using Tool J 34117

2. Using tool J 29189-A (Fig. 6) press the shaft/bearing assembly, seals and impeller out of the pump body as an assembly by applying pressure on the bearing outer race. Marine low mount and standard low mount pumps require removal of the impeller cover, O-ring and snap ring prior to pressing the bearing assembly out of the pump body.
3. Discard all water pump parts except the body on the standard high mount pump. On marine low mount and standard low mount pumps the impeller cover, O-ring, snap ring and body are reusable. The pulley hub on the marine low mount pump is reusable.

NOTICE: The pulley hub on the standard high mount and standard low mount pumps must be

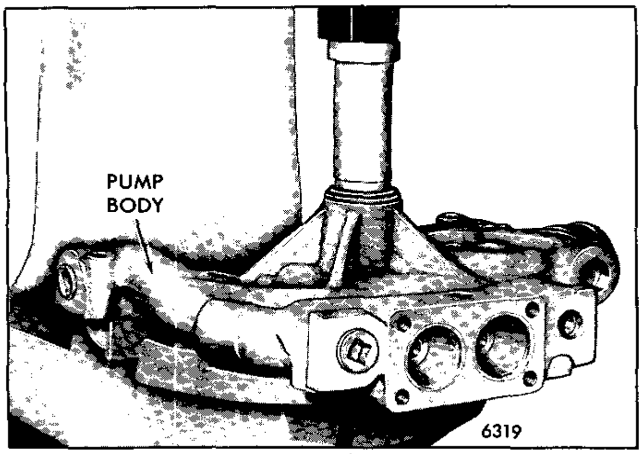


Fig. 6 - Removing Shaft and Bearing Assembly Using Tool J 29189-A

replaced if removed from the shaft assembly. Reuse of the pulley hub after it has once been removed from the shaft assembly will result in excessive pulley hub axial runout.

Inspection

1. Clean the pump body and bearing cavity. A small drill or wire may be required to clean all small passages.
2. Examine the pump body for cracks and excessive impeller contact with the body. Inspect the bearing cavity for scores where the outer perimeter of the water seal assembly seats and seals against the bearing cavity bore. When the bearing cavity bore is scored, a non-hardening sealant should be used in addition to the seal's coating to prevent coolant leakage.
3. Measure the pump's bearing cavity inside bore diameter. This can be accomplished with a telescoping gage and a micrometer. The bore diameter must be within 38.036 - 38.054 mm (1. 497 - 1.498") to provide sufficient bearing press fit. A pump body outside these dimensions must be discarded.

Assemble Pump

1. Use installer tool J 29189-A to apply pressure to the outer race of the bearing (Fig. 7). Press the shaft/bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the pump body. The tool will stop the bearing at the proper depth.

NOTICE: Severe damage (brinelling) to the bearings will result by applying pressure on the end of the shaft.

2. Supporting the water pump shaft (impeller side) on an arbor press, press a new pulley hub on the shaft using tool J 29191 (Fig. 8). Tool J 29191 is designed to position the pulley hub at the correct dimension on the shaft. On the marine low mount pumps only, the pulley hub can be reused and is pressed on until the pulley hub is flush with the end of the shaft.

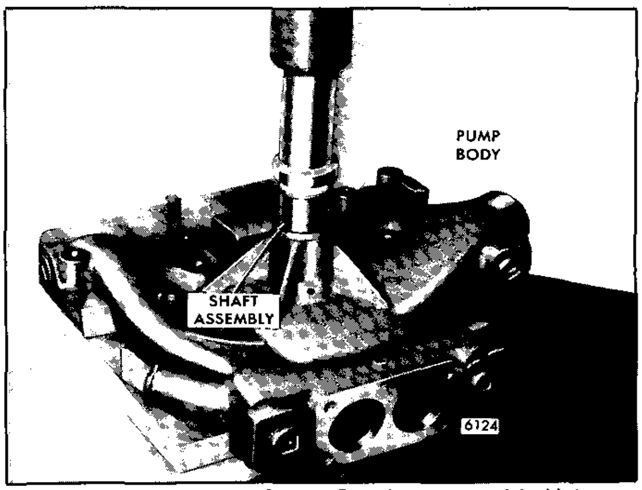


Fig. 7 - Installing Shaft and Bearing Assembly Using Tool J 29189-A

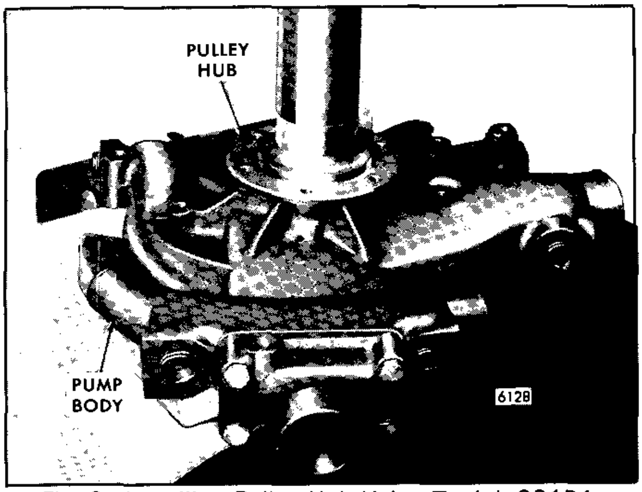


Fig. 8 - Installing Pulley Hub Using Tool J 29191

3. Prior to installing the seals, several water pump pulley hub measurements are required with a magnetic base dial indicator (J 7872). These measurements are not required on the marine low mount water pump pulley hubs. Refer to Fig. 9 for water pump pulley hub total indicator runout (T.I.R.) measurement locations.

Location A = 0.127 mm (0.005") maximum face T.I.R. measured outside of the 101.6 mm (4.0") diameter bolt hole circle.

Location B = 0.076 mm (0.003") maximum radial T.I.R.

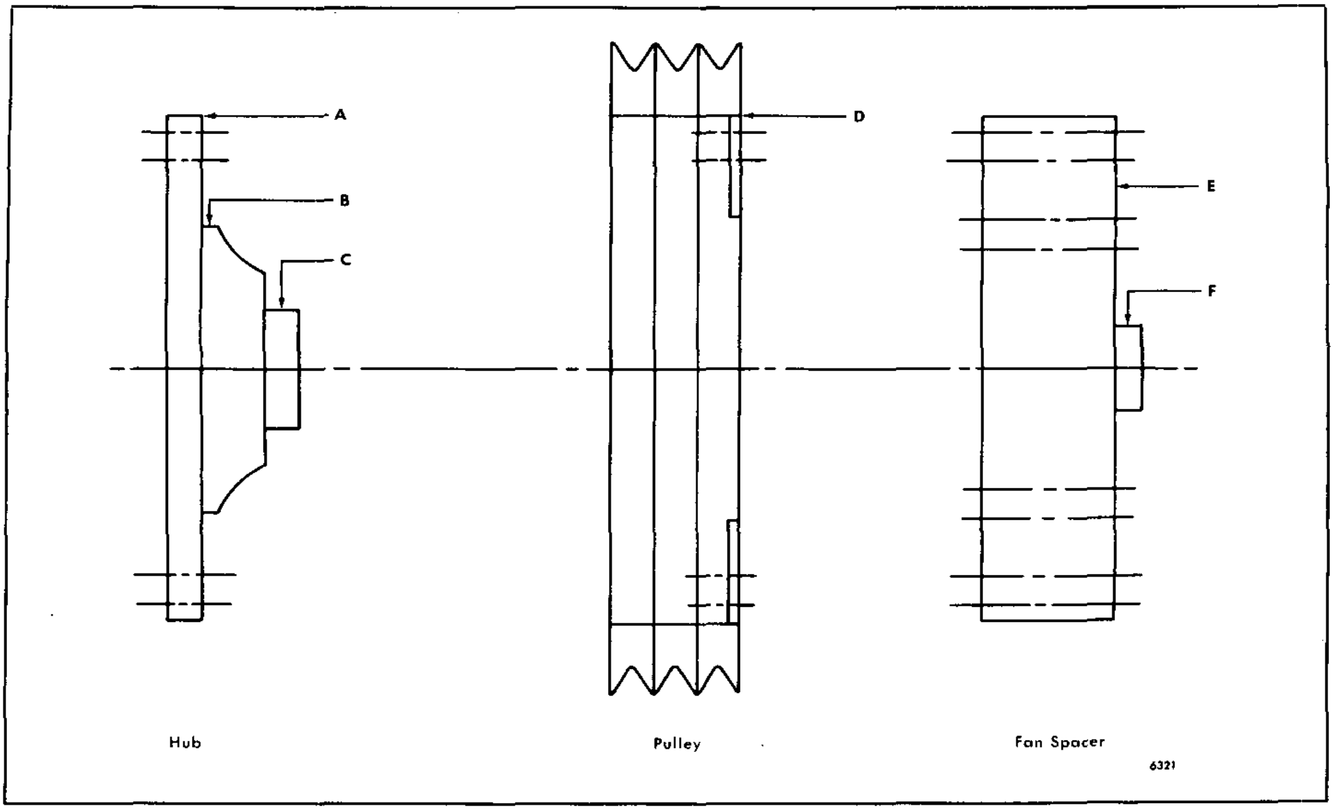


Fig. 9 - Water Pump Pulley Hub, Pulley and Fan Spacer Measurement Locations

Location C = 0.051 mm (0.002") maximum radial T.I.R.

When the water pump pulley hub is found to be outside of the allowable limits, remove the pulley hub (DO NOT REUSE) and inspect the shaft. If the shaft is found to be serviceable, install a new pulley hub and repeat the measurement procedure.

4. Press the lip type oil seal (spring side positioned toward the impeller) into the pump body bore, bottoming against the outer race of the bearing, using tool J 29189-A.
5. Tap the water seal assembly into the pump body bore with a suitable sleeve (15/16" I.D. x 4-1/2" long pipe) which has an inside diameter large enough to fit around the seal and rest on the cartridge lip. The ceramic face of the seal must not be contacted during this operation.
6. Coat the ceramic side of the face mating seal with an ethylene glycol antifreeze and water mixture of 50/50%.

NOTICE: Care must be exercised when coating the ceramic seal, to apply a clean solution only on the ceramic face.

7. Slide the face mating seal assembly over the impeller end of the shaft bottoming against the water seal assembly. The rubber (black) portion of the face mating seal seats against the impeller and the ceramic side (white) seats on the water seal assembly.
8. Support the shaft on the pulley hub end and press the impeller (using its inner hub) on the shaft with tool J 29190-A. Tool J 29190-A is flat on one side and has been machined on the other side to properly position the impeller on the shaft and within the body (Fig. 10).
9. Check the dimensions between the impeller blades and the body with a feeler gage. The impeller blade to body clearance is 0.02-0.91 mm (0.001-0.036") Using a straight edge, check to be sure that the impeller does not protrude beyond the pump body face (surface "B" in Fig. 1) more than 0.39 ± 0.08 mm (0.15" ± .003") maximum after assembly. The impeller may have to be repositioned inward or outward to meet specifications. The impeller can be repositioned using tool J 29190-A. The marine low mount pump requires no further measurements. It will be necessary to install a new O-ring, the original cover on marine low mount and standard low mount pumps. Then secure these parts in place with the original retainer snap ring (Fig.11).
10. Remove the outer snap ring using J 28507, bearing and inner snap ring from the turbine side of the center section.

Install Water Pump

1. Affix a new gasket to the mounting flange of the water pump body.

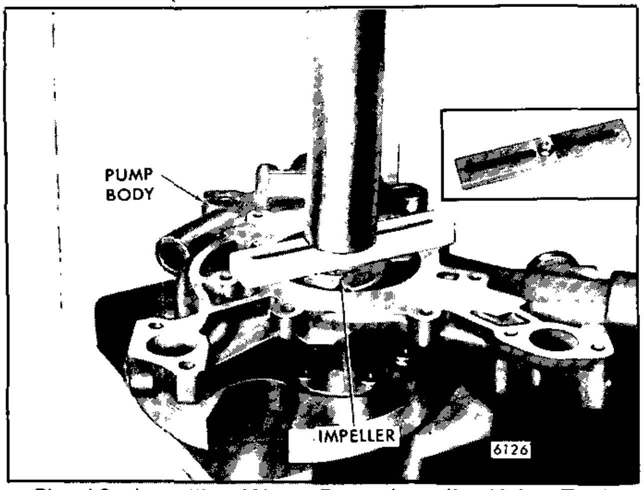


Fig. 10 - Installing Water Pump Impeller Using Tool J 29190-A

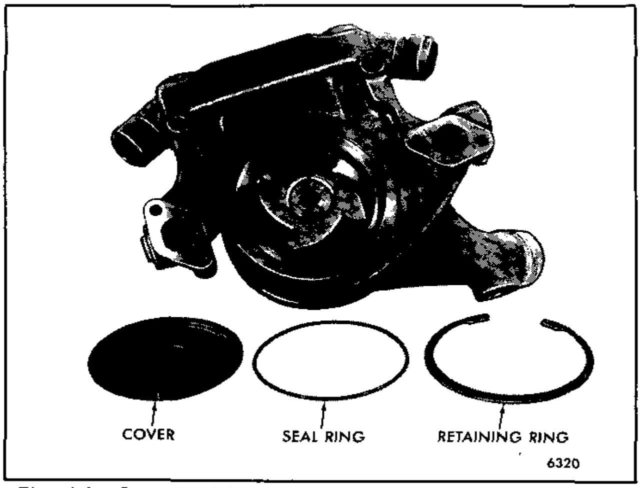


Fig. 11 - Standard Low Mount and Marine Low Mount Water Pump

2. Secure the water pump assembly to the engine front cover with attaching bolts. Torque the M10X70 mm bolts to 46-53 N·m (34-39 lb-ft). Torque the M8X20 mm bolts to 30-34 N·m (22-25 lb-ft).

3. Install all of the hoses that were removed and tighten the hose clamps.

4. The following procedures usually require installation of pulley(s) and fan spacer (where applicable) without fan or fan drive assembly to obtain the required measurements. Measurements are required during the installation of these components to the water pump pulley hub to maintain runout within allowable limits. Installation of the fan or fan drive assembly will be made after the measurement procedure is completed. All mating surfaces of fan drive components should be inspected for smoothness and reworked, as necessary, to eliminate burrs or other imperfections. Refer to Fig. 9 for total indicator runout (T.I.R.) measurement locations.

Location D = 0.229 mm (0.009″) maximum T.I.R. of the pulley(s) face without a spacer. Measurements can be taken with just the pulley(s) attached to the water pump pulley hub or with pulley(s) and fan or fan drive assembly attached.

NOTICE: When an added pulley is utilized, a face runout measurement may not be possible in some applications. If pulley fan runout cannot be measured, a visual inspection is required to insure pulley(s) are properly seated and aligned.

Location E = 0.279 mm (0.011″) maximum T.I.R. of pulley(s) and spacer face with fan or fan drive assembly not attached. Location F = 0.203 mm (0.008″) maximum T.I.R. of spacer's radial pilot. After proper alignment has been achieved, do not loosen the spacer attachment bolts.

When T.I.R. measurements are within allowable limits, install the fan or fan drive assembly. During installation of fan or fan drive assembly, pulley(s) and spacer, indexing to water pump pulley hub must not be changed. It may be desirable to mark components when disassembly is required, thus providing a permanent indexing location to facilitate reassembly.

When maximum T.I.R. measurements are exceeded, the pulley(s) or spacer must be reindexed or repositioned and the measurement procedure repeated.

NOTICE: Face total indicator runout (T.I.R.) at points D and E must be measured outside of fan or fan drive attachment bolt diameter.

Install Fresh Water Pump (Marine)

1. Install the water pump, new gaskets and bolts. Torque bolts to 46-53 N·m (34-39 lb-ft).
2. Install the heat exchanger brackets and bolts to the water pump body. Also, install the fuel line with clips at this time. Torque the bolts to 46-53 N·m (34-39 lb-ft).
3. Reposition the hoses (to water pump from left and right bank cylinder head water outlet elbows) and tighten clamps.
4. Install hose (to R/B exhaust manifold from water pump) and tighten clamps.
5. Install hose (to connecting tube to L/B exhaust manifold from water pump) and tighten clamps.
6. Install hose (from heat exchanger to water pump) and tighten lower clamps.
7. Install the alternator belts, adjust belts using a tension gage. Tighten the retaining bolts.
8. Install the heat exchanger with bolts, tighten bolts to 79-91 N·m (58-67 lb-ft).
9. Position the hoses (to heat exchanger from fresh and raw water pumps) and tighten clamps.

10. Install hose (from thermostat housing to water pump) and tighten clamps.

11. Install deaeration tube and tighten.

Install Fan/Drive Belts

1. Install and tighten the fan belts. Use belt tension gage J 23600-B to adjust the belts for correct tension as outlined in Section 15.1.

NOTICE: Loose belts may place an extremely high impact load on driven component bearings due to the whipping action of the belt. An overtightened belt places unnecessary loads on the component bearings.

2. Close the water drain in the radiator and replace any plugs removed. Fill the cooling system as outlined in Section 5 or according to the original equipment manufacturer's recommendations.
3. Run the engine and check for leaks in the cooling system.

THERMOSTAT

Prior to January, 1985 the temperature of the automotive engine was controlled by two partial blocking type thermostats. Marine and industrial engines incorporated two full blocking type thermostats). Beginning with engines built January, 1985, all engines will use the full blocking thermostats located in the water pump body mounted on the front cover.

OPERATION

At coolant temperature below approximately 71-80°C (160-176°F) depending on the thermostat used - the thermostat valve remains closed and blocks the flow of the coolant to the radiator or heat exchanger. During this period, all of the coolant is circulated through the engine and is directed back to the suction side of the water pump via the bypass passage.

As the coolant temperature rises above approximately 71-80°C (160-176°F) and depending on the thermostat used, the thermostat valve begins to open restricting the bypass system and permitting a portion of coolant to circulate through the radiator or heat exchanger and then through the engine. As the coolant temperature reaches approximately 89-94°C (192-201°F) the thermostat valves are fully open. At this point the automotive bypass system (pre-1985) is mostly blocked off. Bypass systems of engines built beginning January, 1985 will be completely blocked off at this point. The marine and industrial bypass systems are completely blocked off. This allows the coolant to be directed through the radiator or heat exchanger, thereby regulating the coolant temperature.

Remove Thermostats

To remove the thermostats proceed as follows:

1. Drain the cooling system to the necessary level.
2. Remove the hose connections between the thermostat cover and the radiator.
3. Loosen the bolts and remove the thermostat cover from the water pump housing. Discard the gasket. Take out the thermostats.

Inspection

If the action of the thermostat has become impaired due to accumulated rust and corrosion from the engine coolant so that it remains closed, or only partially open, thereby restricting the flow of water, overheating of the engine will result. A thermostat which is stuck in a wide open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold operation will result in a build-up of carbon deposits on the pistons, rings and valves.

The operation of the thermostat may be checked by immersing it in a container of hot water as shown in Fig. 1. Place a thermostat in the container but do not allow it to touch the bottom. Agitate the water to maintain an even temperature throughout the container. As the water is heated, the thermostat valve should begin to open. The opening temperature is usually stamped on the thermostat. Refer to Table 1 for the thermostat operating specifications.

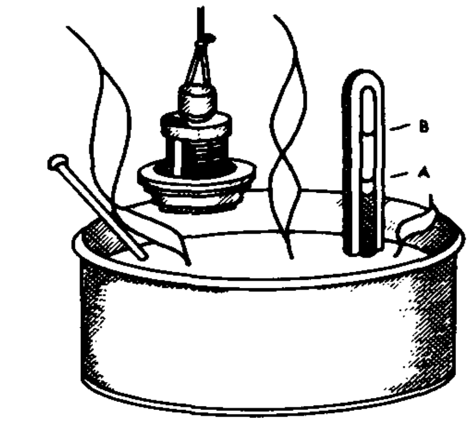


Fig. 1 - Method of Checking Thermostat Operation

THERMOSTATS			
APPLICATION	START TO OPEN TEMPERATURE	FULLY OPEN TEMPERATURE	MINIMUM TRAVEL AT FULLY OPEN TEMPERATURE
AUTOMOTIVE (NEW)	80°-84°C (176°-184°F)	94°C (201°F)	9.1MM (.358")
MARINE (NEW)	75°-79°C (167°-174°F)	89°C (192°F)	9.1MM (.358")
INDUSTRIAL (NEW)	80°-84°C (176°-184°F)	94°C (201°F)	9.1MM (.358")
AUTOMOTIVE (USED)	76°-88°C* (168°-190°F)	94°C* (201°F)	7.62MM (.300")
MARINE (USED)	71°-83°C* (160°-181°F)	89°C* (192°F)	7.62MM (.300")
INDUSTRIAL (USED)	76°-88°C* (168°-190°F)	94°C* (201°F)	7.62MM (.300")

*Approximate

TABLE 1

Clean the thermostat seating surfaces in the water pump and the thermostat cover.

Install Thermostats

Install the thermostat(s) as follows:

1. Place a new gasket on the water pump housing.
2. Insert the thermostats into the housing.
3. Install the thermostat cover and secure it to the housing with four bolts. Torque the M10 x 1.50 mm bolts to 46-53 N·m (34-39 lb-ft).
4. Connect the hose from the radiator to the thermostat cover, align and tighten the hose clamps. After the thermostats have been

installed, close all of the drains and fill the cooling system. Start the engine and check for leaks.

COOLANT PRESSURE CONTROL CAP

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap is designed to permit a pressure of 103 kPa (15 psi) minimum in the system before the valve opens (Fig. 1). This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools (Fig. 2).

CAUTION: Use extreme care when removing the coolant pressure control cap. Remove the cap *slowly* after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

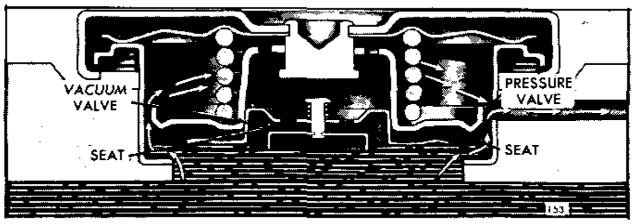


Fig. 1 - Pressure Control Cap (Pressure Valve Open)

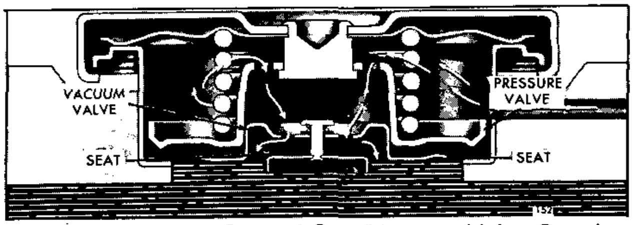


Fig. 2 - Pressure Control Cap (Vacuum Valve Open)

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. Service or replace the cap, as required.

HEAT EXCHANGER

The heat exchanger core assembly consists of a horizontal tube bundle enclosed in a coolant expansion tank (Fig. 1).

In this system of engine cooling, the hot (fresh water) coolant flows from the thermostat housing to the expansion tank, around the outside of the tube bundle and back to the fresh water pump.

The raw water flows horizontally through the tube bundle (lowering the temperature of the engine coolant) and passes out of the heat exchanger to the turbocharger exhaust elbow. Here the raw water is mixed with exhaust gases and is discharged overboard.

A zinc electrode is located in the raw water inlet of the heat exchanger to protect the cooling system from electrolytic action.

The expansion tank provides a means of filling the engine cooling system, as well as space for expansion of the coolant as its temperature rises. An overflow pipe, attached near the top of the tank, provides a vent to the atmosphere.

The length of time a heat exchanger will function satisfactorily before cleaning will be governed largely by the kind of coolant used in the engine, and the kind of raw water used. Soft water, plus a good grade of rust inhibitor or antifreeze, should be used as the engine coolant. The coolant level should be maintained near the top of the expansion tank.

If the heat exchanger fails to cool the engine properly, the core assembly should be examined for foreign deposits.

Remove Heat Exchanger

1. Drain cooling systems (fresh and raw water).
2. Remove hose and clamps (to heat exchanger (H. E.) tank from thermostat housing).
3. Remove hose and clamps (to fresh water pump from H.E. tank).
4. Remove hose and clamps (to raw water pump from H.E. tank).
5. Remove deaeration tube.
6. Remove retaining bolts and H.E. tank. It is not necessary to remove the mounting brackets and bolts from the fresh water pump.
7. Remove the end cover.

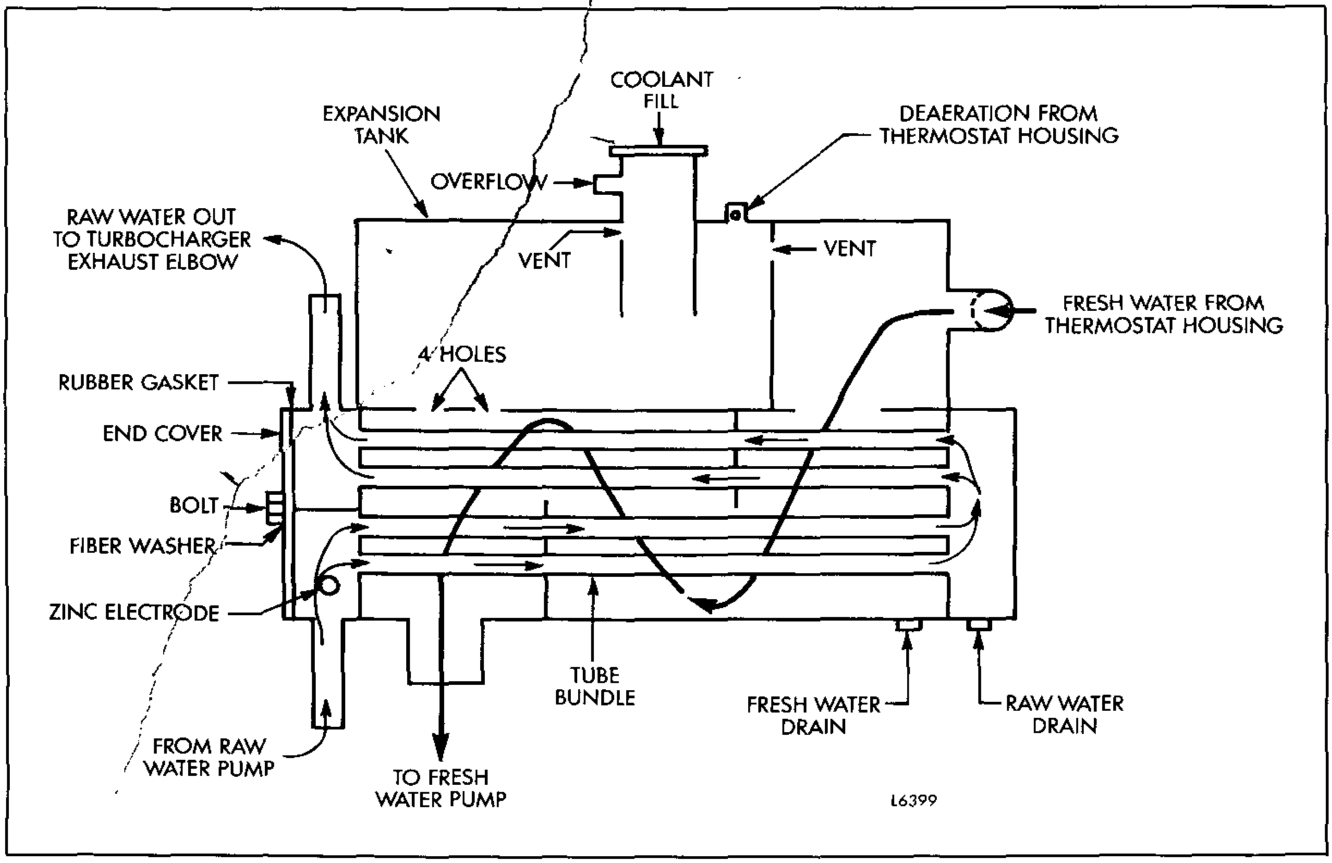


Fig. 1 - Heat Exchanger Schematic

Clean Heat Exchanger Core

When foreign deposits accumulate in the heat exchanger to the extent that cooling efficiency is impaired:

1. Remove the heat exchanger core.
2. With the end cover removed, immerse the heat exchanger core in a scale solvent consisting of one-third (1/3) muriatic acid and two-thirds (2/3) water to which one-half (1/2) pound of oxalic acid has been added to each two and one-half (2-1/2) gallons of solution.
3. Remove the core when foaming and bubbling stops. This usually takes from thirty to sixty seconds.
4. Flush the core thoroughly with clean hot water under pressure.

NOTICE: To prevent drying and hardening of accumulated foreign substances, the heat exchanger core must be cleaned as soon as possible after removing it from service.

Inspect Zinc Electrodes

The electrode should be inspected at least once every season, depending on the location of the boat.

Clean pitted electrodes with a wire brush. Should excessive pitting or erosion be found, the electrode and holder should be discarded and a new one installed in the heat exchanger.

Inspection

1. With a new end cover gasket and fiber washer, reinstall the end cover.
2. Torque the end cover bolt to 3 N·m (2 lb-ft) maximum.
3. Using suitable plugs, block off the raw water in and out connections of the heat exchanger.
4. Be sure that the raw water drain plug is installed and that the pressure cap and fresh water drain plug are removed.
5. Remove the zinc electrode and install an adaptor and an air line into the opening.
6. Immerse the heat exchanger vertically into a water tank preheated to 82-93°C (180-200°C).
7. Agitate the heat exchanger in the water to remove all air.
8. Apply 138 kPa (20 psi) and observe for air bubbles.
9. If a leak is found, the heat exchanger must be repaired or replaced before reinstallation.

Install Heat Exchanger

1. Install heat exchanger tank and retaining bolts. Torque bolts to 79-91 N·m (58-67 lb-ft).
2. Install deaeration tube and tighten.
3. Install hose and tighten clamps (to fresh water pump from H.E. tank).
4. Install hose and tighten clamps (to raw water pump from H.E. tank).
5. Install hose and tighten clamps (to H.E. tank from thermostat housing).
6. Refill the fresh and raw water systems and check for leaks.

RAW WATER PUMP (JABSCO)

Raw water for lowering the temperature of the engine coolant is circulated through the heat exchanger by a right-hand rotating positive displacement pump (Fig. 1). The pump is attached to a mounting bracket located at the right front of the engine.

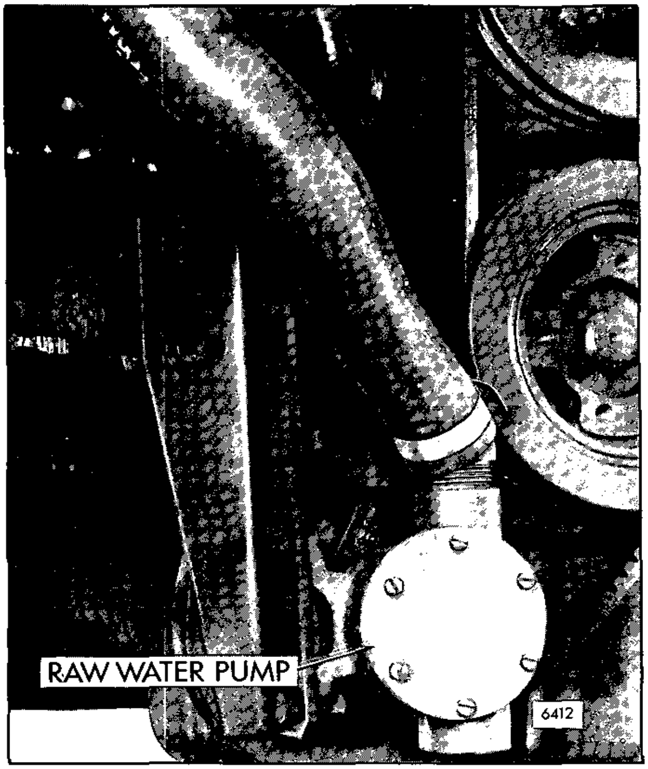


Fig. 1 - Raw Water Pump Mounted on Engine

An impeller, splined to the end of the drive shaft, is self-lubricated by the water pump and should not be run dry for longer than 30 **seconds** . Lack of liquid will damage the impeller.

A wear plate in the impeller compartment prevents wear of the end cover and can be reversed if wear on the plate becomes excessive. A slot machined in the outer periphery of the wear plate registers with a dowl in the pump housing, thus preventing it from rotating with the shaft.

A rotary type seal assembly seals against leakage along the shaft.

Operation

The pump can be operated in a clockwise or counterclockwise direction. Raw water is drawn into the pump through an inlet opening and discharged through the outlet opening.

Lubrication

The shielded type double row ball bearing is filled with lubricant when assembled. No further lubrication is required.

Remove Raw Water Pump from Engine

1. Drain the raw water system.
2. Loosen the hose clamps at the outlet elbow and intermediate tube and slide the hose along the tube.
3. Loosen the hose clamps at the inlet elbow and the inlet tube and slide the hose along the tube.
4. Remove the bolts and lock washers holding the pump to the mounting bracket.

Disassemble Pump

Refer to Fig. 2 and disassemble the pump as follows:

1. Using a three leg puller or press, remove the drive pulley and key.
2. Remove the end cover screws, end cover and gasket.
3. Grasp the hub of the impeller with water pump pliers and withdraw from the body.
4. Remove the cam screw and cam. Clean Permatex from the cam and body bore.
5. Remove the wearplate.
6. Insert a screwdriver between O.D. of the outer bearing seal and the bearing bore and pry out the seal.
7. Remove the bearing-to-body retaining ring.
8. Press on the impeller drive end of the shaft to remove the shaft and bearing assembly.
9. Using extreme care not to mar the body bore, insert a screwdriver between the O.D. of the inner bearing seal and bearing seal bore and pry out the seal.
10. Remove the ceramic seal seat and seat gasket from the shaft. Press the carbon seal seat out of the body towards the impeller bore.
11. Remove the bearing-to-shaft retaining ring.
12. Support the bearing inner race and press on the drive end of the shaft to remove the shaft from the bearing. Do not attempt to remove the bronze bushing which is pinned to the shaft.
13. Inspect all parts for wear or damage and replace where necessary.

Inspect Pump Parts

After disassembly, clean all parts thoroughly, except the bearing. *Shielded bearings must not be washed* ; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the bearing clean on the outside, and then inspect it. Hold the inner race and revolve the outer race slowly

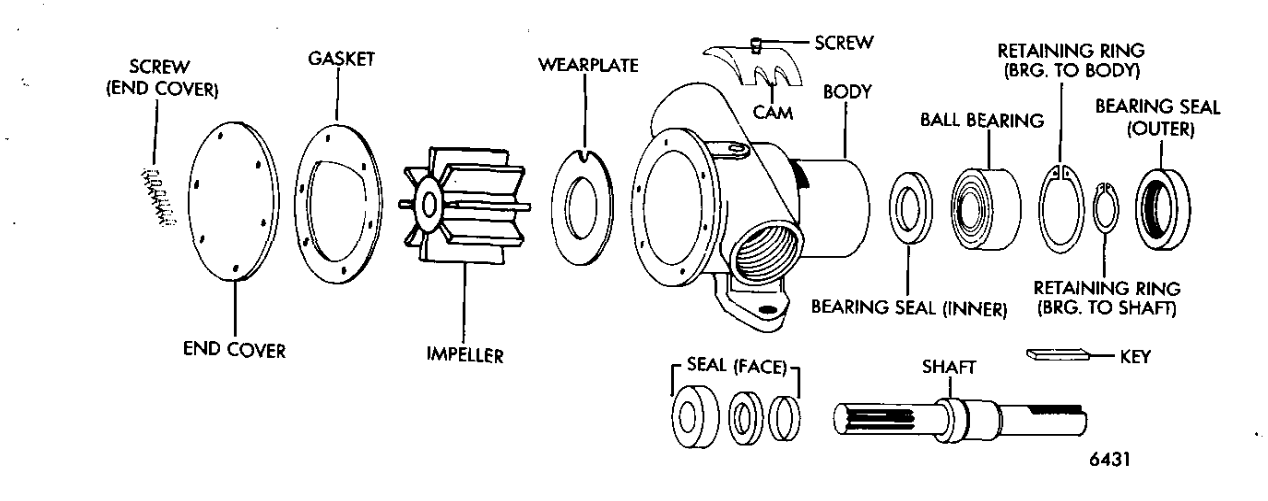


Fig. 2 - Raw Water Pump and Relative Location of Parts

to detect possible wear or rough spots. Replace the bearing if it is worn or does not roll freely.

Examine the parts of the seal assembly and the ball bearing seals. Discard any parts that have been cut, cracked or otherwise damaged.

Inspect the oil seal contact surfaces of the shaft for scratches or grooves. Smooth the surfaces with a crocus cloth wet with fuel oil, if scratched.

Inspect the impeller to make sure the bond between the neoprene and the metal is good. If the impeller blades have a permanent set, a new impeller should be used.

Remove any burrs the from wear plate. If wear on the plate is excessive, it may be reversed when the pump is assembled.

Assemble Pump

Using new parts where required, refer to Fig. 2 and assemble the pump as follows:

1. Lubricate the inner bearing seal lip with grease and press the seal into the body bearing seal bore with the lip facing away from the bearing bore.
2. Press the shaft into the bearing, using care to support the inner race of the bearing.
3. Install the bearing-to-shaft retaining ring with the flat side towards the bearing.
4. Insert the splined end of the shaft through the bearing bore until the bearing contacts the body.
5. Pressing on the bearing outer race, install the bearing into the bore.
6. Install the bearing-to-body retaining ring in the body groove with the flat side towards the bearing.
7. Lubricate the outer bearing seal lip with grease and with the lip outwards, press into bearing bore until it is flush with the body.
8. Lubricate the rubber grommet in the ceramic seal seat with water and install on the shaft, with the grommet towards the bearing. Install the seal (carbon toward ceramic seat) in the seal bore and press flush with bottom of impeller bore.
9. Install the wearplate in the body bore, aligning the slot in the wearplate with the dowel pin in the body.
10. Lightly coat the cam screw threads and the top side of the cam with a non-hardening waterproof sealant and install in the body with the cam screw.
11. Support the impeller end of the pump and press on the drive pulley until it is flush with the end of the shaft.

NOTICE: Do not hammer the pulley on the shaft; this may damage bearings or seal.

12. Lubricate the impeller bore and end surfaces of the impeller with a light coat of Vaseline and start the impeller into the bore with a rotary motion until the splines engage. Using a plastic hammer, lightly tap the impeller into the bore.
13. Turn the impeller several turns in that direction in which it will normally operate, to position the blade properly.
14. Install the gasket and end cover and secure with the end cover screws.

Install Raw Water Pump on Engine

The pump may be installed by reversing the procedure used for removal.

NOTICE: Do not overtighten the drive belt. An overtight belt will reduce the pump bearing life and may side load the crankshaft. Adjust the belt tension so that a firm push with the thumb at a

point midway between the two pulleys will depress the belt 1/2".

Torque the water pump mounting bolts to 58-66 N·m (42-48 lb-ft).

Drain Pump

The raw water pump is not provided with a drain valve. If freezing temperatures are anticipated and the engine is not going to be operated or the engine is being placed in storage, it is recommended that the raw water pump impeller housing be drained in addition to draining the engine cooling system.

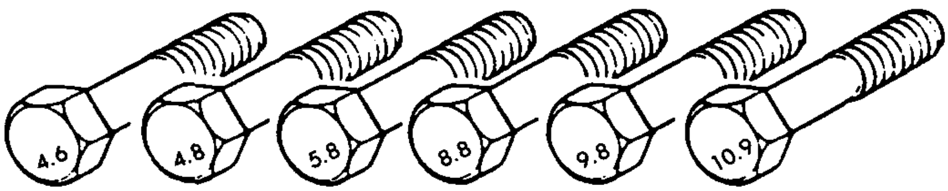
Drain the raw water pump impeller housing by carefully pulling the pump cover away from the housing after loosening the screws. If the gasket is damaged, the cover will have to be removed and the gasket replaced.

After the pump has been drained, replace the cover and tighten the screws.

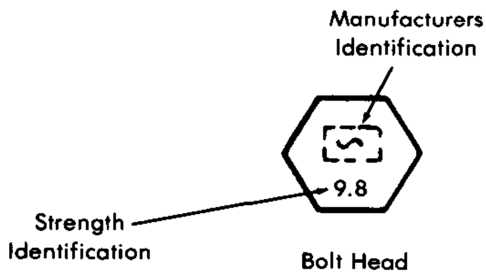
STANDARD METRIC BOLT AND NUT TORQUE SPECIFICATIONS

Thread Size Diameter × MM Per Thread	BOLT CLASSES / TORQUES		
	8.8 Nm/LB-FT	9.8 Nm/LB-FT	10.9 Nm/LB-FT
M5 × .8	None used	5.0-6.0/3.7-4.4	7.0-8.0/5.2-5.9
M6 × 1.0	" "	10-12/7.4-9.0	13-15/10-11
M8 × 1.25	" "	23-27/17-20	30-34/22-25
M10 × 1.50	" "	46-53/34-39	58-66/43-49
M12 × 1.75	" "	79-91/58-67	101-116/74-86
M14 × 2.0	" "	126-144/93-106	160-184/118-136
M16 × 2.0	" "	192-220/142-162	245-280/181-207
M20 × 2.5	334-384/246-283	None used	478-550/353-406

STANDARD METRIC BOLTS



Metric Bolts — Identification class numbers correspond to bolt strength — Increasing numbers represent increasing strength.



SERVICE TOOLS

TOOL NAME	TOOL NO.
Water Pump	
Impeller - remover and installer	J 29190-A
Bearing and oil seal - remover and installer	J 29189-A
Pulley hub - remover and installer	J 29191
Pulley hub puller (Marine)	J 34117
Dial indicator	J 7872
Belt tension gage	J 23600-B

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

The fan and radiator cooled engine is equipped with air cooled exhaust manifolds.

The outlet flange is at the rear when the manifold is mounted on the engine. Some N. A. engines have the outlet flange pointing down.

Stainless steel heat shields are used in the exhaust ports of the cylinder head.

The exhaust manifold is attached to the cylinder head with eight hardened bolts that incorporate a special locking thread design.

EXHAUST MANIFOLD

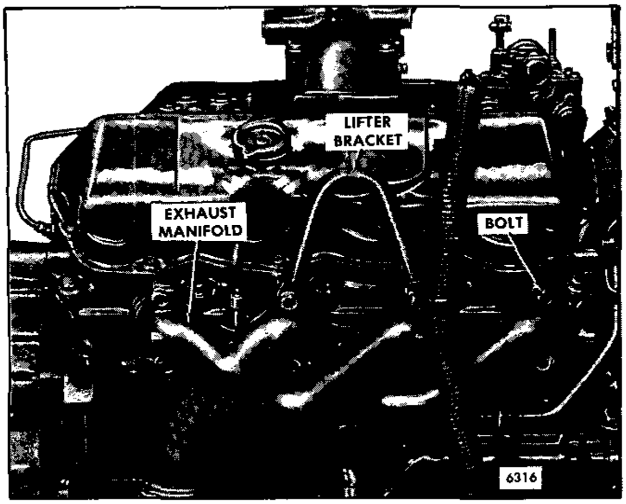


Fig. 1 - Exhaust Manifold Mounting

One cast iron exhaust manifold (Fig. 1) is attached to each cylinder head. The exhaust manifolds have a circular outlet. Marmon flange type clamps are used to connect the exhaust inlet tube to the turbocharger at the rear of the engine. On non-turbocharged engines the exhaust manifold outlet is at the rear or points down depending on the model.

Remove Exhaust Manifold

1. Loosen two clamps at the exhaust inlet tube between the manifold and turbocharger. Remove clamps and tube.

2. Remove two manifold bolts which attach the lifter and take away the lifter.

3. Loosen, but do not remove, one of the center manifold bolts. Remove the other bolts.

4. Support the manifold and remove the remaining bolt.

5. Remove the manifold and gasket from the cylinder head. Discard the gasket.

6. Remove the heat shield from each exhaust port.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the manifold. Clean the manifold and check for cracks, especially in the holding areas.

Clean the exhaust port heat shields and check them for dents and cracks.

Install Exhaust Manifold

1. Insert a heat shield into each exhaust port. Be sure the lip is properly seated in the counter-bore.

2. Position a gasket on the manifold with word "Out" against the manifold mounting face.

3. Insert two bolts and attach the manifold and gasket to the cylinder head.

4. Install the lifter bracket using the (2) two longer bolts in the upper holes.

5. Install all of the remaining bolts and tighten them to 58-66 Nm (43-49 lb-ft) torque.

6. Connect the exhaust inlet tube between the manifold and turbocharger. Tighten the 1/4"-28 clamp nuts to 12-15 Nm (9-11 lb-ft) torque.

7. On non-turbocharged engines with the exhaust outlet mounted down, connect it to the exhaust piping.

EXHAUST MANIFOLD (WATER-COOLED)

The one-piece water-cooled manifold (Fig. 1) is cast with an integral water jacked surrounding the exhaust chamber. The manifold connects to a water-cooled crossover turbo mount at the rear of the engine. Coolant is supplied from the water pump via a tube or hose to the front end of the manifold. The coolant circulates through the manifold to the crossover turbo mount into the water-cooled *turbocharger and exits at the top of the turbocharger* via a tube returning the coolant to the cylinder head water outlet elbow.

A plug is provided in the bottom of the exhaust manifold for draining moisture condensed from the exhaust gases.

Remove Exhaust Manifold

1. Drain the cooling system.
2. Remove the coolant supply tube/hose and clamps.
3. Remove the four bolts to the crossover turbo mount.
4. Remove the exhaust manifold bolts (8 bolts - 4 short-top, 4 long-bottom) and the exhaust manifold.
5. Remove the gaskets.

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Visually check for cracks or other damage.

Install Exhaust Manifold

1. Install the exhaust manifold using new gaskets (one manifold gasket and one gasket between the manifold and the crossover turbo mount). Torque *the manifold bolts to* 58-66 N·m (43-49 lb-ft).

   Torque the crossover turbo mount bolts to 58-66 N·m (43-49 lb-ft).
2. Install the coolant supply tube/hose and clamps.
3. Fill the cooling system and check for leaks.

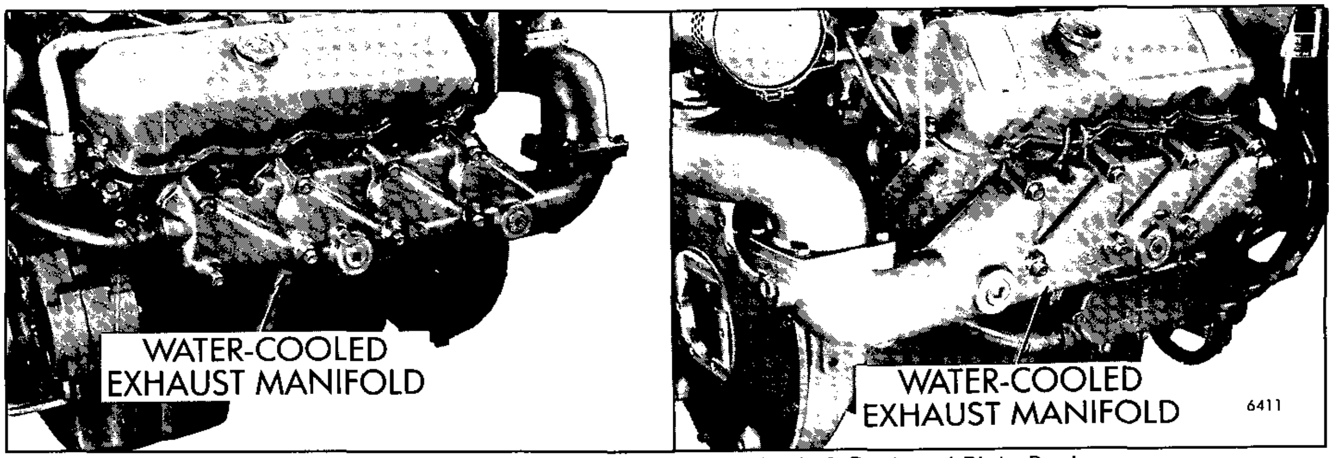


Fig. 1 - Typical Water-Cooled Exhaust Manifolds - Left Bank and Right Bank

SECTION 7

ELECTRICAL EQUIPMENT, PROTECTIVE SYSTEM

CONTENTS

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of a starting motor, a battery-charging alternator, a transistor combination voltage regulator, current regulator and cutout relay to protect the electrical system, a storage battery and the necessary wiring. An electric operated shutdown solenoid is also mounted on the engine governor.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC-Delco service outlet, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts for electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, repair serivce and parts are available through AC-Delco branches and repair stations.

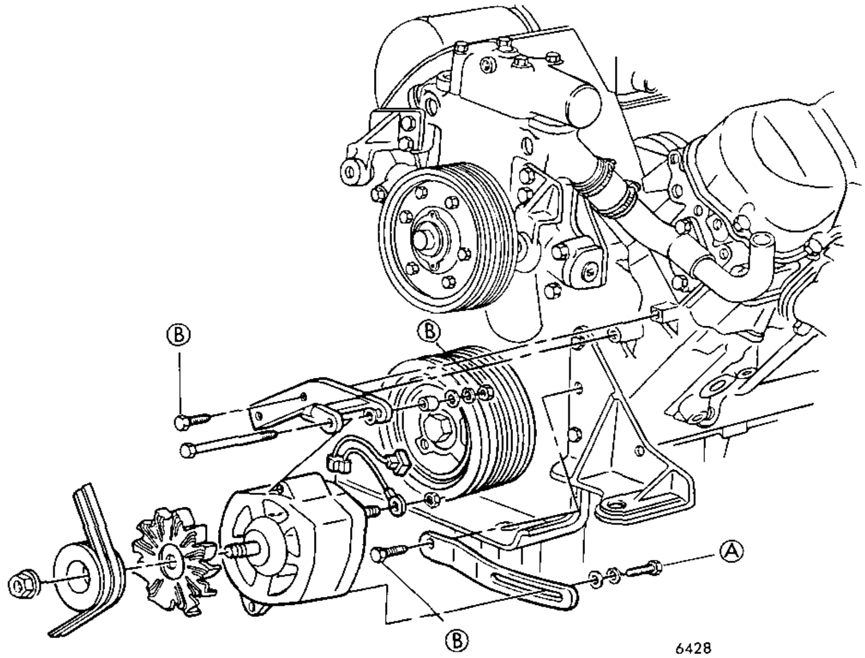
BATTERY-CHARGING ALTERNATOR

Remove Alternator

1. Loosen the alternator adjusting bracket bolts, reposition the alternator and remove the drive belts.
2. Remove the bolts and the alternator.

Install Alternator

1. Install the alternator and bolts loosely.
2. Install the drive belts and adjust.
3. Tighten the nuts and bolts. See Fig. 1 for bolt and nut torques.
4. Check drive belts with a recommended tension gage such as J 2360-B. Readjust belts, if necessary.



TORQUES
Ⓐ– 30 - 34 Nm (22 - 25 lb. ft.)
Ⓑ– 58 - 66 Nm (43 - 49 lb. ft.)

Fig. 1 - Relative Location of Parts (8.2L Marine Alternator)

STARTING MOTOR

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a Sprag-Type overrunning clutch.

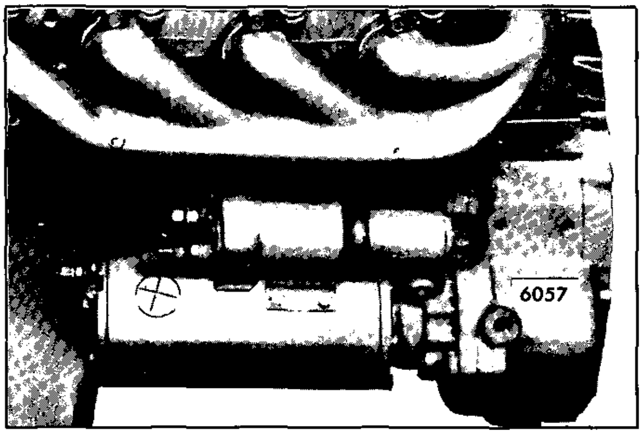


Fig. 1 - Starting Motor Mounting

A solenoid switch, mounted on the starting motor housing, operates the overrunning clutch drive by linkage and a shift lever. When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever is totally enclosed to protect them from dirt, water and other foreign material.

In the heavy-duty clutch type (Fig. 2) an oil seal, between the shaft and the lever housing, and a linkage seal prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing on the Sprag clutch type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

Starter with Heavy Duty Clutch

The nose housing in Fig. 2 is attached to the lever housing by six bolts located around the outside of the housing. Relocate the nose housing as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs from the unused holes if a twelve hole starter mounting flange is used.
2. Turn the nose housing to the required position.

NOTICE: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failure.

3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid, and six neoprene plugs, if a twelve hole starter mounting flange is used.
4. Tighten the screws to 18-23 N·m (13-17) lb-ft torque.

Lubrication

The starting motor bearings (bushings) are lubricated by oil saturated wicks which project through each bronze bushing (one at each end and one at the center) and contact the armature shaft. Oil can be added to each wick by removing a pipe plug which is accessible on the outside of the motor (refer to Section 15.1).

Flywheel Ring Gear

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

REMOVE STARTING MOTOR

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.
2. Disconnect the starting motor cables and solenoid wiring.

NOTICE: Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the three bolts which secure it to the flywheel housing. Then,

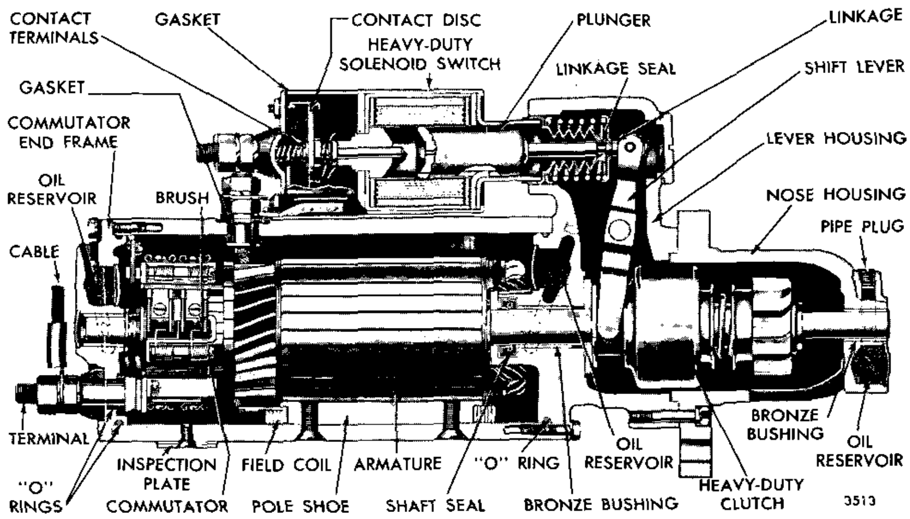


Fig. 2 - Cross Section of Starting Motor

pull the motor forward to remove it from the flywheel housing.

Check the starting motor, if required, in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the starter attaching bolts to 192-220 N·m (142-162 lb-ft) torque.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 1.8 - 3.4 N·m (16-30 lb-in) torque and the 1/2" x 13 connections to 27-34 N·m (20-25 lb-ft) torque.

Remove Marine Starting Motor

1. Remove the ground strap or cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.
2. Disconnect the starting motor cables and solenoid wiring.

NOTICE: Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the two nuts and loosen the bolt. A captive flange head bolt is used in the third hole to mount the starter. (Part of the starter assembly). Then, pull the motor to remove it from the flywheel housing adaptor cover (Fig. 3).

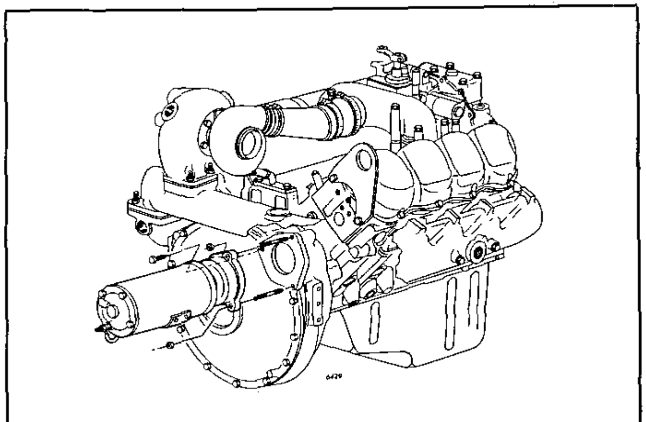


Fig. 3 - Removing or Installing Marine Starting Motor

Install Marine Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the two (2) attaching nuts to 129-142 N·m (95-105 lb-ft). Torque the bolt to 245-280 N·m (181-207 lb-ft).

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 1.8-3.4 N·m (16-30 **lb-in**) torque and the 1/2" x 13 connections to 27-34 N·m (20-25 lb-ft) torque.

ENGINE SHUTDOWN SOLENOID

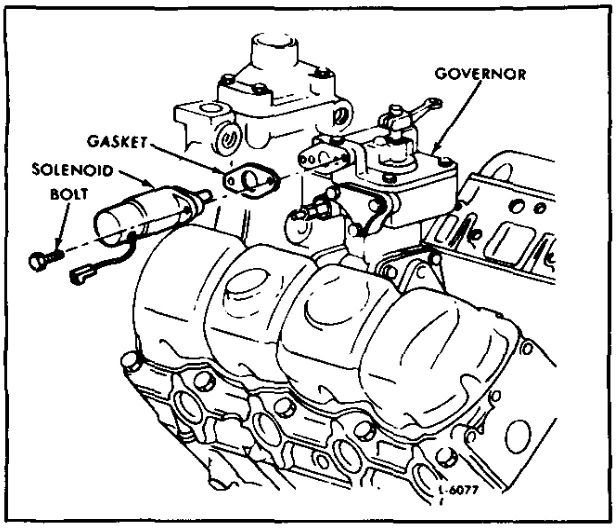


Fig. 1 - Location of Solenoid on Governor

An electrically operated pull type shutdown solenoid is attached to the governor cover (Fig. 1). It is sealed with a gasket and attached with two bolts.

The solenoid must be energized to the run position or removed from the governor prior to connecting the governor linkage to the rack control shaft or engine overspeed may occur. This precaution is necessary because the solenoid is designed to hold the fuel shutdown in the stop position at all times except when the solenoid is energized.

If the injector racks are held in the full fuel position and connected to the governor while the shutdown is in the stop position, the injector will be locked at full rack (maximum fuel).

> **NOTE:** *The control and rack travel must be checked after any adjustments and prior to engine start.*

Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks move to the no fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

> **CAUTION:** An overspeeding engine can result in engine damage which could cause personal injury.

> **NOTE:** If inadequate voltage or current is supplied to the solenoid at engine start, the plunger will not pull all the way back and the primary coil will stay energized causing an overheat condition and solenoid failure. Always return the switch to "off" when a starting attempt is aborted.
> **NOTE:** It is important to provide vehicle wiring of sufficient size to minimize voltage drop in the solenoid circuit. As a general guideline, 10 guage wire is recommended as minimum size to prevent the above condition.

SHUTDOWN SOLENOID TEST PROCEDURE

A shutdown solenoid is used on 8.2L engine mechanical governors. This solenoid uses a two-section coil: a high-current coil to pull the plunger into the solenoid body and a low-current coil to hold the plunger in. The high-current coil is disconnected by an internal cutout switch after the plunger is pulled into its seated/position. If the solenoid malfunctions, the following tests may be used to determine the cause:

TEST 1 - Pull in Coil Check

Procedure

Set a conventional ohmmeter to its lowest resistance range and carefully zero it. Attach the ohmmeter leads to the solenoid leads and read the ohmmeter.

Results

A reading of less than 1 ohm indicates the pull in coil is operating. A reading of greater than 1 ohm indicates a malfunction in the pull in coil.

TEST 2 - Hold in Coil Check

Procedure

With the ohmmeter leads connected to the solenoid, push the plunger in as far as possible and hold it in that position. Read the ohmmeter.

SOLENOID OPERATING TEMPERATURE	0°F −17.5C	72°F 22.2C	250°F 121C
MINIMUM VOLTAGE AT SOLENOID	6	7	10

TABLE 1

Results

A reading of eleven (11) ohms ±two (2) ohms indicates that the hold in coil is operating. If the reading exceeds ±two (2) ohms, the hold in coil is malfunctioning.

If the solenoid passes these tests but still malfunctions, make a voltage test with the solenoid energized on the engine. Voltage at the solenoid terminals must equal or exceed the following minimum values to provide proper solenoid operation (Table 1). Low voltage at the terminals may be the result of low battery voltage, improper wiring, improper ground connections or excessive wire lengths.

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, coolant and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough under ordinary operating conditions but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, cold weather starting devices are available.

The engine cylinder block has a 3/4 " threaded drain hole located in the front right side of the block which can be used for an immersion type coolant heater.

> **NOTE:** Starting aids are not intended to correct deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel-air mixture.

PRESSURIZED CYLINDER STARTING AID

Operation

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. 1) as follows:

1. Turn the key switch to start the engine.

2. Pull out the "Quick Start" knob for one or two seconds, then release it.

3. Repeat the procedure if the engine does not start on the first attempt.

> **NOTE:** Do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

Service

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.

2. Lubricate the actuator cable.

3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.

4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

> **CAUTION: Do not actuate the starting aid more than once with the engine stopped. *Over-loading the engine intake system with this high volatile fluid could result in an explosion.***

7. Check the fluid cylinder for hand tightness.

Spray Can

The most familiar type of ether starting aid is the pressurized spray can. Starting an engine using an ether spray can is a two man operation requiring one to direct the ether at the air cleaner and a second to start the engine.

When using an ether spray can use caution to insure that excessive starting fluid is not used. To much ether could cause a momentary burst of uncontrolled engine speed and could cause engine damage.

> **CAUTION:** Ether is highly flammable and toxic. Misuse can be dangerous. Always follow the starting aid manufacturers recommendations

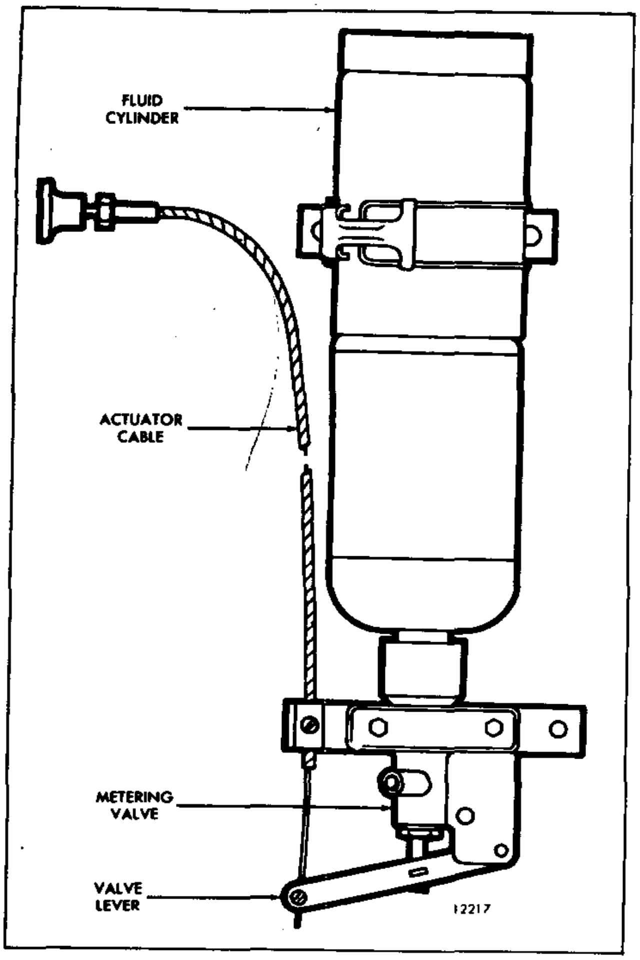


Fig. 1 - "Quick Start" Assembly

regarding storage, use and amount of ether injected.

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTE:** When preparing to start a new or overhauled engine or an engine that has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart*, Section 15.1.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with a coolant specified under *Engine Coolant* in Section 13.3. The coolant level should be within two inches of the filler neck to allow for fluid expansion.

Close the vents, if used, after filling the cooling system.

On marine installations, prime the raw water cooling system and open any sea cocks in the raw water pump intake line. Prime the raw water pump by removing the pipe plug or electrode provided in the pump outlet elbow and pour water in the pump.

> **NOTE:** Failure to prime the raw water pump may result in damage to the pump impeller.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 25 psi (172 kPa) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use lubricating oil as specified under *Lubrication Specifications* in Section 13.3. Then, remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with lubricating oil as specified under *Lubrication Specifications* in Section 13.3. Then, prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms. The oil pump also requires prelubrication. Refer to Section 4.1.

Turbocharger

When a turbocharger is replaced, it must be prelubricated by pouring oil into the oil supply inlet before it is installed on the engine. Rotate the shaft to coat the bearings with oil. If the engine has been in storage, pressure prelubricate the system through an oil gallery in the cylinder block. This will also prelubricate the turbocharger.

Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers pressure (20 psig - 138 kPa at idle speed).

> **CAUTION:** Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Check the oil level and, if necessary, fill the transmission case, marine gear or torque converter supply tank to the proper level with the lubricant specified by the manufacturer.

Fuel System

Fill the fuel tank with the fuel specified under *Fuel Specifications* in Section 13.3.

If the unit is equipped with a fuel supply shutoff valve, it must be opened. Special note should be taken of the direction of flow through any check valves used in the system to be sure of their proper installation.

To ensure prompt starting and even running, the fuel system must be purged of air and full of fuel from the supply tank to the restricted fitting at the fuel return line. To accomplish this, a manual priming pump, such as J 5956 or an electrical type priming pump can be adapted easily to the fittings provided on the primary or secondary filters. To be sure the injectors are lubricated and in order to have less resistance to priming flow caused by the static fuel pump, priming through the secondary filter is preferred. The system should be primed until no air is present in the fuel flow from the return line. Pressure should not exceed 15 psi (103 kPa) for ease of handling and safety reasons.

Pressurization of the fuel tank, although not recommended, can be used with controlled air pressure and a modified filler cap (do not exceed 15 psi or 103 kPa). If this system is used, be sure the return line from the head is disconnected to bleed the system, or no flow will occur. Reverse flow through the return line should be avoided to prevent reverse flushing of filters and flushing residue from the fuel tank into the injectors. Special provisions may have to be made on dual tanks to prevent loss of pressure from the vent on the tank opposite the tank being pressurized.

Priming is not always necessary if the filter elements are filled with fuel when installed and the manifolds in the head are not drained of fuel. Prolonged use of the starter motor and engine fuel pump to prime the system can result in damage to the starter, fuel pump, injectors and erratic running of the engine, due to the amount of air in the lines and filters from the supply tank to the cylinder head.

Engines equipped with starting devices dependent on compressed air or gas reservoirs should always be primed prior to initial start-up, otherwise reserve pressure can be exhausted. Injectors can be damaged from lack of lubrication and cooling.

> **NOTE:** Under no circumstances should a starting aid such as ether be used to run the engine until the fuel system is primed. Injector damage will occur if this method is used. The heat generated by the external fuel source will cause the tips to be damaged when the fuel cools them. The plunger and bushing can be scored from running without lubrication.

Lubrication Fittings

Fill all grease cups and lubricate all fittings with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

> **NOTE:** When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

Starting at air temperatures below 40° F (4° C) requires the use of a cold weather starting aid.

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used. Reference should be made to these instructions before

attempting a cold weather start. Reference Section 12.6.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no-load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the *run* position; on hydraulic governors, make sure the stop knob is pushed all the way in. Then, press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

NOTE: To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Trouble Shooting Charts* in Section 15.2.

Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm-up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

Normal engine coolant temperature is 77-90° C (170-195° F).

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 10 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the lubricating oil specified under *Lubrication Specifications* in Section 13.3.

Cooling System

Remove the radiator or heat exchanger tank cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or an ethylene glycol base antifreeze.

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

NOTE: When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the *neutral* position.

2. Allow the engine to run at half speed or slower with no load for four or five minutes, then, turn the key switch to the *stop* position.

NOTE: If the engine is equipped with a turbocharger bring the engine to idle speed so that the turbocharger has a chance to slow down and dissipate the heat generated by the exhaust turbine, through the lubricating oil, before the engine is shut down and oil pressure is lost.

Emergency Stopping

1. To stop the engine, turn the key switch to the *stop* position.

2. To stop the engine with the shutdown solenoid removed, move the governor stop lever to the *stop* position.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

Inspection

Make a visual check for leaks in the fuel, lubricating and cooling systems.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to the *Lubrication and Preventive Maintenance Chart* in Section 15.1 and perform all of the daily maintenance operations. Also, perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which became apparent to the operator during the last run.

ENGINE OPERATING CONDITIONS

The engine operating charts are included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and the instruments are accurate, before attemping to make corrections to the engine.

V8 - 8.2 Federal and California 4087- 7100 (4A53 Injector)

	3000 rpm
Lubrication System	
Lubricating oil pressure kPa (psi):	
Normal	241-345 (35-50)
Minimum for safe operation	207 (30.0)
*Lubricating oil temperature degr. C. (degr. F.) - max.	110-127 (230-260)
Air System	
Air inlet restriction kPa (inches water) - full load max.:	
Dirty air cleaner	5.0 (20)
Clean air cleaner	2.5 (10)
Crankcase pressure kPa (inches water) - max.	0.423 (1.7)
Exhaust back pressure kPa (inches mercury) - max.:	
Full load	9 (2.5)
Fuel System	
Fuel pressure at inlet manifold kPa (psi):	
Normal with 2.8 mm (.110 ") restriction	310-483 (45-70)
Minimum	241 (35)
Fuel spill liters per min. (gpm) - minimum at no-load:	
2.8mm (.110 ") restriction	4.9 (1.3)
Fuel pump suction at pump inlet kPa (inches mercury) - max.:	
Clean system	20 (6.0)
Dirty system	41 (12.0)
Cooling System	
Coolant temperature degr. C. (degr. F.) - normal	82°-92°C (180°-198°F)
Coolant inlet restriction kPa (inches mercury) - max.	10 (3.0)
Cylinder Leak Down	
Pressure per cylinder at Top Dead Center:	
Minimum ... 48 psi**	

*The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be 10° lower than the oil pan temperature.

**Use cylinder leakage tester J29006 to determine psi.

V8 -8.2T Federal and California 4087 - 7300 4C65 Injector

	3000 rpm
Lubrication System	
Lubricating oil pressure kPa (psi):	
Normal	241-345 (35-50)
Minimum for safe operation	207 (30.0)
*Lubricating oil temperature degr. C. (degr. F.) - max.	110-127 (230-260)
Air System	
Air inlet restriction kPa (inches water) - full load max.:	
Air cleaner (dirty)	5.0 (20)
Air cleaner (clean)	2.5 (10)
Crankcase pressure kPa (inches water) - max.	.747 (3.0)
Exhaust back pressure kPa (inches mercury) - max.:	
Full load	10 (3.0)
Fuel System	
Fuel pressure at inlet manifold kPa (psi):	
Normal with 2.8 mm (.110") restriction	310-483 (45-70)
Minimum	241 (35)
Fuel spill liters per min. (gpm) - minimum at no-load:	
2.8 mm (.110") restriction	4.9 (1.3)
Fuel pump suction at pump inlet kPa (inches mercury) - max.:	
Clean system	20 (6)
Dirty system	41 (12)
Cooling System	
Coolant temperature degr. C. (degr. F.) - normal	82°-92°C (180°-198°F)
Coolant inlet restriction kPa (in. hg.) - max.	10 (3.0)
Cylinder Leak Down	
Pressure per cylinder at Top Dead Center :	
Minimum. . . . . 48 psi**	

*The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be 10° lower than the oil pan temperature.

**Use cylinder leakage tester J29006 to determine psi.

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair that uses replacement piston rings, pistons, or bearings, for example, the engine should be "Run-In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine, to determine if the engine will perform to published specifications and to permit a physical inspection for leaks of any kind. It is an excellent method for detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 5.6° C (10° F) higher than the water inlet temperature. A 5.6° C (10° F) rise across an engine is recommended; however, a 8.3° C (15° F) temperature rise maximum can be permitted.

Thermostats are required to control the coolant flow and to help maintain a constant engine temperature. Therefore, be sure that they are in place and fully operative or the engine may overheat during the Run-In. Furthermore, a deaeration line must be installed in the uppermost portion of the engine to prevent any overheat problems during Run-In.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

A basic engine includes only those components actually necessary to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Engine Run-In Check*. The following items are included on the basic engine: fuel pump, water pump and governor. The fan and battery-charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, a proper record of this fact should be made on the *Engine Test Report*. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb-ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower
T = torque in lb-ft
RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample in this section).

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

8.2L ENGINE TEST REPORT

Date: ____________ Unit Number: ____________
Repair Order Number: ____________ Model Number: ____________
Natural or Turbo: ____________ Injector Size: ____________
Rated F/L RPM: ____________ Max. N/L RPM: ____________
Idle RPM: ____________

A. PRESTART

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL OIL SYSTEM	3. FILL COOLING SYSTEM

B. START UP AND IDLE FOR 30 SECONDS.

START ________ STOP ________ OIL PRESSURE ________ WATER TEMPERATURE ________

C. WARM UP — 5 MINUTES START ________ STOP ________

RPM MAX. GOVERNED SPEED	LOAD 50%	OIL PRESSURE	WATER TEMPERATURE
1. LUBE OIL LEAKS	2. FUEL OIL LEAKS	3. COOLANT LEAKS	4. LOOSE BOLTS

D. RUN IN — 5 MINUTES START ________ STOP ________

RPM MAX. GOVERNED SPEED	LOAD 75%	OIL PRESSURE	WATER TEMPERATURE

E. RESET GOVERNOR FOR FINAL TEST IF NECESSARY

F. FINAL RUN IN — 20 MINUTES START ________ STOP ________

RPM MAX. GOVERNED SPEED	LOAD 100%	CRANKCASE PRESSURE AT F/L	EXHAUST BACK PRESSURE AT F/L
LUBE OIL PRESSURE AT F/L	LUBE OIL TEMPERATURE AT F/L	FUEL OIL TEMPERATURE AT F/L	FUEL OIL PRESSURE AT F/L
WATER TEMPERATURE AT F/L	TURBO BOOST PRESSURE AT F/L	LUBE OIL PRESSURE AT IDLE	IDLE RPM

REMARKS:

OK________ Reject________ Dynamometer Operator________ Date________

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Water temperature gage installed in the thermostat housing or water outlet manifold.

c. Adaptor for connecting a pressure gage or water manometer to the crankcase.

d. Fuel pressure gage at the cylinder head.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7"
Inches of mercury = psi x 2.04"

NOTE: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

Run-In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

PRESTART (Section A)

1. Fill the lubrication system as outlined under *Lubrication System – Preparation for Starting Engine First Time* in Section 13.1.

2. Prime the fuel system as outlined under *Fuel System – Preparation for Starting Engine First Time* in Section 13.1.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing* in Section 14.2.

5. Preliminary injector rack adjustment must be made as outlined in Section 14.

6. Preliminary governor adjustments must be made (Section 14).

NOTE: Prior to starting a turbocharged engine, make sure that the turbocharger has been prelubricated by adding oil to the turbocharger oil inlet or pressurizing the lubrication system.

ENGINE RUN-IN (Section B)

After performing the prestart steps, be sure all test stand water valves, fuel valves, etc. are open. Also, inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

NOTE: Turbocharged engines should be operated at idle for at least one minute after starting to assure oil supply and pressure to the turbocharger bearings.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events and specifications for the Test and Run-In. Also, refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-In. If a governor is encountered which cannot be adjusted to this speed, remove the governor assembly and repair as required.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Warm-Up - 5 minutes* (Section C).

The engine should be run at this speed and load for 5 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on the *Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Engine Run-In Schedule.* During this time, engine performance will improve as new parts begin to "seat in". Record all data.

RUN-IN INSPECTION (Section D)

Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

> **NOTE:** Allow turbocharged engines to idle at least 3 minutes in order for the turbocharger to cool and reduce speed before shutdown.

FINAL RUN-IN (Section F)

After all of the tests have been made and the *Engine Test Report* is completed through Section "E", the engine is ready for final test. This portion of the test and Run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 5 minutes at the same speed and load used for warm-up. If piston rings or bearings have been replaced as a result of problems during the warm-up, the entire Run-In must be repeated as though the Run-In and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the *Operating Conditions* in Section 13.2 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Run-In at full load. It should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in *psi* after being taken at engine speeds indicated in the *Operating Conditions*, Section 13.2.

Check the *crankcase pressure* while the engine is operating at maximum Run-In speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run-In indicating that new rings are beginning to "seat-in".

Refer to the *Final Engine Run-In Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In. Apply the load thus determined to the dynamometer. The engine should be run at this speed and load for 5 minutes. While making the Final Run-In, the engine should develop the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Run-In. This will ordinarily require a governor adjustment.

All information required in Section "F", Final Run-In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

FUEL OILS FOR DETROIT DIESEL ENGINES

GENERAL CONSIDERATIONS

The quality of fuel oil used for high-speed diesel engine operation is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should show at least 98% by volume recovery when subjected to ASTM D-86 distillation. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and ASTM Designation D-975 (grades 1-D and 2-D) meet the completely distilled criteria. The differences in properties of VV-F-800 and ASTM D-975 fuels are shown in the following table.

FEDERAL SPECIFICATION & ASTM DIESEL FUEL PROPERTIES

Specification or Classification Grade	VV-F-800 DF-1	ASTM D-975 1-D	VV-F-800, DF-2 NORTH AMERICA	VV-F-800, DF-2 OTHER	ASTM D-975 2-D
Flash Point, min.	38°C 100°F	38°C 100°F	52°C 125°F	56°C 133°F	52°C 125°F
Carbon Residue (10% residuum), mass % max.	0.15	0.15	0.35	0.20	0.35
Water & Sediment, % by vol, max.	—	0.05	—	—	0.05
Ash, % by wt., max.	0.01	0.01	0.01	0.02	0.01
Distillation Temperature, 90% by vol. recovery, min.	—	—	—	—	282°C 540°F
max.	288°C 550°F	288°C 550°F	338°C 640°F	357°C 675°F	338°C 640°F
End Point max.	330°C 626°F	—	370°C 698°F	370°C 698°F	—
Viscosity Kinematic, cSt, min. @ 40°C	1.3	1.3	1.9	1.8@20°C	1.9
Saybolt, SUS, min. @ 100°F	—	—	—	—	32.6
Kinematic, cSt, max. @ 40°C	2.9	2.4	4.1	9.5@20°C	4.1
Saybolt, SUS, max. @ 100°F	—	34.4	—	—	40.1
Sulfur, mass % max.	0.50	0.50	0.50	0.70	0.50
Cetane No., min.	45	40.0	45	45	40.0

FUEL CLEANLINESS

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier.

FUEL SULFUR CONTENT

The *sulfur content* of the fuel should be as low as possible to avoid premature wear, excessive deposit formation, and minimize the sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies.

The detrimental effect of burning high sulfur fuel is reflected in Detroit Diesel lube oil change interval recommendations. Detroit Diesel recommends that the Total Base Number (TBN-ASTM D-664) of the lube oil be monitored frequently and that the oil drain interval possibly be reduced. Consult the FUEL OIL SELECTION CHART.

FUEL OIL SELECTION CHART

Application	General Fuel Classification	Final Boiling Point (Max.)	Cetane Number (Min.)	Sulfur Content (Max.)	Cloud Point
City Buses	No. 1-D	550°F 288°C	45	0.30	SEE NOTES
	Winter No. 2-D*	675°F 357°C	45	0.50	
	Summer No. 2-D*	357°C	40	0.50	
All Other Applications	Winter No. 2-D	675°F 357°C	45	0.50	SEE NOTES
	Summer No. 2-D	675°F 357°C	40	0.50	

*No. 2-D diesel fuel may be used in city coach engine models that have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

Note 2: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5,000 ft.

IGNITION QUALITY - CETANE NUMBER

There is a delay between the time the fuel is injected into the cylinder and the time that ignition occurs. The duration of this delay is expressed in terms of cetane number (rating). Rapidly ignited fuels have high cetane numbers (50 or above). Slowly ignited fuels have low cetane numbers (40 or below). The lower the ambient temperature, the greater the need for a high cetane fuel that will ignite rapidly.

Difficult starting may be experienced if the cetane number of the fuel is too low. Furthermore, engine knock and puffs of white smoke may be experienced during engine warmup especially in severe cold weather when operating with a low cetane fuel. If this condition is allowed to continue for any prolonged period, harmful fuel derived deposits will accumulate within the combustion chamber. Consult the FUEL OIL SELECTION CHART.

DISTILLATION END POINT

Fuel can be burned in an engine only after it has been vaporized. The temperature at which fuel is completely vaporized is described as the *distillation end point* (ASTM D-86). The distillation (boiling) range of diesel fuels should be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed, and load. Mediocre to poor vaporization is more apt to occur during severe cold weather and/or prolonged engine idling and/or light load operation. Therefore, engines will show better performance operating under the conditions described above when lower distillation end point fuels are used. Consult the FUEL OIL SELECTION CHART.

CLOUD POINT

The *cloud point* is that temperature at which wax crystals begin to form in diesel fuel. The selection of a suitable fuel for low temperature operability is the responsibility of the fuel supplier and the engine user. Consult the FUEL OIL SELECTION CHART.

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel Allison designs, develops and manufactures commercial diesel engines to operate on diesel fuels classified by the ASTM as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800.

Burner fuels (furnace oils or domestic heating fuels) generally require an open flame for satisfactory combustion. The ignition quality (cetane rating) of burner fuels (ASTM D-396) is poor when compared to diesel fuels (ASTM D-975).

In some regions, however, fuel suppliers may distribute one fluid that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) sometimes identified as burner, furnace, or residual fuel. Under these circumstances, the fuel should be investigated to determine whether the properties conform with those indicated in the FUEL OIL SELECTION CHART.

The FUEL OIL SELECTION CHART also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. *Distillation Range, Cetane Number, Sulfur Content, and Cloud Point* are four of the most important properties of diesel fuels that must be controlled to insure satisfactory engine operation. Engine speed, load, and ambient temperature all influence the selection of diesel fuels with respect to distillation range and cetane number.

All diesel fuels contain a certain amount of sulfur. Too high a sulfur content results in excessive cylinder wear. For most satisfactory engine life, fuels containing less than 0.5% sulfur should be used.

During cold weather engine operation the *cloud point* (the temperature at which wax crystals begin to form in diesel fuel) should be 10°F (6°C) below the lowest expected fuel temperature in order to prevent clogging of the fuel filters by wax crystals.

A reputable fuel oil supplier is the only one who can assure you that the fuel you receive meets the *Distillation End Point, Cetane Number, Sulfur Content, and Cloud Point* property limits shown in the FUEL OIL SELECTION CHART. The responsibility for clean fuel that meets Detroit Diesel Allison specifications lies with the fuel supplier as well as the operator.

At temperatures below +32°F (0°C) particular attention must be given to cold weather starting aids for efficient engine starting and operation.

NUMEROUS FUELS BURNED IN DETROIT DIESEL ENGINES

Numerous fuels meeting the properties shown in the FUEL OIL SELECTION CHART may be used in Detroit Diesel engines. The table (next page) shows some of the alternate fuels (some with sulfur and/or cetane limits) that have been burned in Detroit Diesel engines. Among these are No. 1 and No. 2 diesel fuels, kerosene, aviation turbine (jet) fuels, and burner fuels.

PROPOSED ASTM D-975, GRADE 3-D

Detroit Diesel Allison does NOT recommend the use of proposed grade 3-D diesel fuel in any of its engines. This grade of fuel was proposed, but not accepted by, the ASTM.

The grade 3-D which was proposed is undesireable in that it possesses poor ignition quality (i.e., lower cetane), allows greater sulfur content (up to 0.70% by weight), allows the formation of more carbon deposits (Conradson carbon residue), and allows the blending of heavier, more viscous boiling point fractions that are difficult to burn. The latter tend to increase combustion chamber deposits. This type of fuel usually manifests poor cold

FUELS BURNED IN DETROIT DIESEL ENGINES

ASTM Designation	Federal Standard	Military Spec.	NATO Code	Grade	Description/Comments
D-975				1-D 2-D	Diesel Fuel
D-396				1, 2	Burner Fuel (Furnace Oil) ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. % and the Minimum Cetane No. Is 45. (See Fuel Oil Selection Chart).***
	VV-F-800		F-54	1, 2	DF-1 Winter Grade, DF-2 Regular Grade
	VV-F-800		F-56		DF-A (Arctic Grade). Limited Supply For Military.
		MIL-T-5624		JP-5	Kerosene
D-1655		MIL-T-83133	F-34	JP-8	Jet A-1, Kerosene Type Plus Special Anti-Icer
D-1655			F-35		Jet A, Kerosene
		MIL-F-16884	F-76	DFM	Diesel Fuel - Marine (DFM). ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. %.***
		MIL-F-5161		JP-6	Referee Grade JP-5 Type Jet Fuel. Limited Quantities Supplied To Military Only.

weather properties (wax formation tendencies). In addition, the poor ignition quality adversely affects noise and emission levels.

A comparison of ASTM D-975 grade 2-D and the proposed grade 3-D fuel properties is shown in the following table.

USING DRAINED LUBE OIL IN DIESEL FUEL

Detroit Diesel Allison *does not recommend* the use of drained lubricating oil in diesel fuel. Furthermore, Detroit Diesel Allison will not be responsible for any detrimental effects which it determines resulted from this practice.

BURNING MIXTURES OF DIESOHOL AND GASOHOL AND/OR ADDING ALCOHOL AND/OR GASOLINE TO DIESEL FUEL

Very small amounts of isopropyl alcohol (isopropanol) may be used to preclude fuel line freeze-up in winter months. No more than ONE PINT of isopropyl alcohol should be added to 125 GALLONS of diesel fuel for adequate protection.

Commercially marketed DIESOHOL or GASOHOL or GASOLINE should never be added to diesel fuel. An explosive and fire hazard exists if these blends are mixed and/or burned.

COMPARISON OF ASTM D-975 GRADE 2-D AND PROPOSED GRADE 3-D PROPERTIES

Property	Grade: Recommended 2-D	Grade: Not Recommended 3-D
Cetane No., Min.	40.0	37.0
Sulfur, WT. %, Max.	0.50	0.70
Carbon Residue On 10% Residuum, %, Max.	0.35	0.40
Viscosity @ 40° Celsius, Centistokes	1.9 - 4.1	2.0 - 7.0
Distillation		
deg. Celsius (Fahrenheit)		
90% Recovery, Max.	338 (640)	360 (680)

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpt has been taken from a policy statement of General Motors Corporation:

"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in fuels and lubricants."

Therefore, Detroit Diesel Allison does not recommend the use of any supplementary fuel or lubricant additives. These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tune-up compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds.

NOTICE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's *fuel or lubricating recommendations* may not be within the coverage of the warranty.

LUBRICATING OILS FOR DETROIT DIESEL ENGINES

GENERAL CONSIDERATIONS

All diesel engines require heavy-duty lubricating oils. Basic requirements of such oils are lubricating quality, high heat resistance, and control of contaminants.

LUBRICATING QUALITY. The reduction of friction and wear by maintaining an oil film between moving parts is the primary requisite of a lubricant. Film thickness and its ability to prevent metal-to-metal contact of moving parts is related to oil viscosity. The optimums for Detroit Diesel engines are SAE 40 or 30 weight.

HIGH HEAT RESISTANCE. Temperature is the most important factor in determining the rate at which deterioration or oxidation of the lubricating oil will occur. The oil should have adequate thermal stability at elevated temperatures, thereby precluding formation of harmful carbonaceous and/or ash deposits.

CONTROL OF CONTAMINANTS. The piston and compression rings must ride on a film of oil to minimize wear and prevent cylinder seizure. At normal rates of consumption, oil reaches a temperature zone at the upper part of the piston where rapid oxidation and carbonization can occur. In addition, as oil circulates through the engine, it is continuously contaminated by soot, acids, and water originating from combustion. Until they are exhausted, detergent and dispersant additives aid in keeping sludge and varnish from depositing on engine parts. But such additives in excessive quantities can result in detrimental ash deposits. If abnormal amounts of insoluble deposits form, particularly on the piston in the compression ring area, early engine failure may result.

Oil that is carried up the cylinder liner wall is normally consumed during engine operation. The oil and additives leave carbonaceous and/or ash deposits when subjected to the elevated temperatures of the combustion chamber. The amount of deposits is influenced by the oil composition, additive content, engine temperature, and oil consumption rate.

OIL QUALITY is the responsibility of the oil supplier. (The term "oil supplier" is applicable to refiners, blenders, and rebranders of petroleum products). Oil quality can also be affected by handling cleanliness, contamination, dirt, water, etc.

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience), and proper filter maintenance will provide the best assurance of satisfactory oil performance.

It should be noted that lube oil manufacturers may reformulate an oil while maintaining the same API classification, or may reformulate to a new API classification and continue the brand name designation. For example, SE oils being reformulated to SF letter code classification may perform differently after this reformulation. A close working relationship with the lube oil manufacturer should be maintained so that any reformulation can be reviewed and a decision made as to its effect on continued satisfactory performance.

COLD WEATHER OPERATION

Two important considerations relate to satisfactory operation under cold ambient temperature conditions. These are: (1) the ability to crank the engine fast enough to secure starting, and (2) providing adequate lubrication to internal wearing surfaces during starting and warm-up. Once started and warmed up, external ambient temperatures have little effect on internal engine temperatures. Both cold weather considerations can be adequately met through proper lube oil selection and the use of auxiliary heat prior to starting. Auxiliary heat can be used in the form of jacket water and oil pan heaters, hot air space heaters applied to engine compartments, or some combination of these.

Proper oil selection and oil heat can assure lubricant flow immediately upon starting. Improper oil selection and oil heat may result in starting with cold oil congealed in the oil pan, and little or no oil flow for lubricating internal parts once the engine has started.

Proper oil selection and jacket water heating can assure cranking capability by maintaining an oil film on cylinder walls and bearing surfaces in a condition which provides low friction, and hence, less cranking effort to achieve cranking speeds necessary for reliable starting. Improper oil selection and jacket water heating may result in congealed oil films on cylinder walls and bearing surfaces, which result in high friction loads and more cranking effort than is available, thus preventing sufficient cranking speeds to assure reliable starting.

LUBE OIL SPECIFICATIONS

API PERFORMANCE DESIGNATIONS, LUBE SUPPLIER, AND BRAND NAMES

Lubricants are blended to meet specific industry accepted tests developed by the American Society for Testing and Materials (ASTM). The service for which these products are intended is defined by the American Petroleum Institute (API). The lube supplier markets these products under a specific brand or trade name. The container identification indicates whether the contents meet or exceed specific API letter code designations (example: SF, CD).

RECOMMENDATION

Lubricating oils that meet the following performance levels, viscosity grades, sulfated ash limits and zinc requirements are recommended for Detroit Diesel engines. It is also recommended that the oil supplier provide to the user evidence of satisfactory performance of his products in Detroit Diesel engines.

LUBE OIL PERFORMANCE LEVELS

Lubricants are formulated to meet all the performance criteria defined in either commercial (API) and/or military specifications. Table L-1 shows the current commercial industry and military oil performance levels. The API letter designations are defined in SAE recommended practice J-183 published in the SAE Handbook.

Specific oil performance level recommendations for Detroit Diesel engines are indicated in Table L-1.

TABLE L-1
LUBE OIL PERFORMANCE LEVELS

API PERFORMANCE DESIGNATION		COMPARABLE MILITARY SPECIFICATION	RECOMMENDED FOR USE IN DDA ENGINES		COMMENTS & CURRENT API OR MILITARY QUALIFICATION STATUS
DIESEL ENGINES	GASOLINE ENGINES		2-CYCLE	4-CYCLE	
CB	—	MIL-L-2104A (Supplement 1)	YES	NO	Obsolete, still limited availability.
CC	—	MIL-L-2104B	YES	NO	Obsolete, still readily available.
CD	—	MIL-L-45199B (Series 3)	YES	NO	Still limited availability.
CC	SE	MIL-L-46152	YES	YES	Obsolete Diesel performance, intended for passenger cars burning gasoline.
CC	SF	NONE	YES	YES	Primarily for passenger cars burning gasoline.
CD	SC	MIL-L-2104C	YES	YES	Current spec. for heavy duty diesel powered military vehicles, acceptable for commercial diesel powered vehicles.
CD	SE		YES	YES	Diesel performance requirements are current. Gasoline fueled passenger cars performance requirements are obsolete.
CD	SF		YES	YES	Meet current diesel & gasoline performance requirements.
—	SF		NO	YES	Service station lubes.

VISCOSITY GRADES

Table L-2 shows the viscosity grade selection chart for Detroit Diesel 4-cycle, 8.2 liter engines. Various multigrades having numerous oil performance levels are acceptable as shown. Single grade SAE-30 may be used when ambient temperatures are above 50°F (10°C).

TABLE L-2
VISCOSITY — SAE GRADE SELECTION CHART

Ambient Temperature		ENGINE SERIES								
		149		92, 71, 53			8.2L			
		2-CYCLE		2-CYCLE			4-CYCLE			
Deg. Fahr.	Deg. Celsius	First	Second	First	Second	Third	First	Second	Third	Fourth
↕ 50	↕ 10	** SAE 40	SAE 30	SAE 40	SAE 30	None	15W-40	10W-40	20W-40	30
50 ↕ 32	10 ↕ 0	SAE (40)	SAE 30 *	SAE (40)	SAE 30 *	None	* 15W-40	* 10W-40	* 20W-40	None
32 ↕ 0	0 ↕ −18	SAE (40)	SAE (30)	SAE (40)	SAE (30)	* 15W-40	(15W-40)	* 10W-40	(20W-40)	None
0 ↕ −25	−18 ↕ −32	SAE (40)	SAE (30)	SAE (40)	SAE (30)	(15W-40)	(15W-40)	(10W-40)	(20W-40)	None

( ) Numbers in parentheses indicate that starting aids are required.

* Usually unaided starts can be accomplished.

** SAE 50 grade lube oil is recommended if the top tank coolant temperature is 195°F or above. (CAUTION: Do not use SAE-50 grade lube oil when or where cold ambient temperatures prevail.)

OIL CHANGES

CONDITION A: THE SULFUR CONTENT OF THE DIESEL FUEL IS LESS THAN 0.50% BY WEIGHT

Table L-3 shows the initial oil drain intervals recommended for all Detroit Diesel engines. Oil drain intervals may be increased or decreased depending upon the condition of the lubricant. Used lube oil analysis guidelines, indicating contamination limits, are shown elsewhere in Table L-4. DDA recommends that if the total base number (TBN by ASTM D-664) is reduced to 1.0 or if the TBN (ASTM-2896) is reduced to 2.0, the oil should be drained immediately.

CONDITION B: THE SULFUR CONTENT OF THE DIESEL FUEL IS GREATER THAN 0.50% BY WEIGHT

The detrimental effects of burning high sulfur fuel are known in industry. The use of high sulfur diesel fuel may be unavoidable in some locations.

The use of high TBN/ash oils (TBN greater than 10, ash up to 2.500% by weight) is recommended to counteract corrosion.

The trend manifested by extremely high TBN oils (TBN greater than 20/ash between 2.000 to 2.500% by weight) is to drop several TBN numbers and then level off. The condition of the used oil under these circumstances is that it has retained some alkaline reserve (neutralization power) but will become overloaded with suspended solids that tend to become insoluble, resulting in the formation of excessive engine deposits. Therefore, when using high TBN/ash oils, a rule of thumb for oil change intervals is to drain the oil when the TBN drops to one-half of the new oil TBN. *Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary.* These differences manifested by the various high TBN/ash oils will influence the drain interval.

TABLE L-3

RECOMMENDED LUBE OIL DRAIN AND FULL-FLOW FILTER CHANGE INTERVALS WHEN BURNING LOW SULFUR DIESEL FUELS (0.5% BY WT. OR LESS)*

SERVICE APPLICATION	ENGINE SERIES	ENGINE DESIGN	LUBE OIL DRAIN INTERVAL**	FILTER CHANGE INTERVAL
Hwy. Truck & Inter-City Buses	71 & 92 8.2L	2-Cycle 4-Cycle	20,000 Miles 6,000 Miles	20,000 Miles 6,000 Miles
City Transit Coaches & Pick-Up & Delivery Truck Service (Stop-and-Go) Short Distance	53, 71, 92 8.2L	2-Cycle 4-Cycle	12,000 Miles 6,000 Miles	12,000 Miles 6,000 Miles
Industrial & Marine	53, 71, 92 8.2L	2-Cycle 4-Cycle	150 Hours 150 Hours	150 Hours 150 Hours
Large Industrial & Marine	149 (NA) 149 (T)	2-Cycle 2-Cycle	500 Hrs. or One Yr. 300 Hrs. or One Yr.	500 Hrs. or One Yr. 300 Hrs. or One Yr.
Stationary (Stand-By) Engines	53, 71, 92 149 8.2L	2-Cycle 2-Cycle 4-Cycle	150 Hrs. or One Yr. 150 Hrs. or One Yr. 150 Hrs. or One Yr.	150 Hrs. or One Yr. 150 Hrs. or One Yr. 150 Hrs. or One Yr.
Generator Sets (Prime Power)	53, 71, 92	2-Cycle	500 Hrs. or One Mo.	500 Hrs. or One Mo.

* See sections indicating Detroit Diesel's recommendations when burning high sulfur content (0.5% by Wt. or more) diesel fuels.

** May be increased or decreased, depending on the results obtained from used lube oil analysis.

FULL-FLOW FILTER CHANGE PERIOD

Table L-3 shows the DDA recommended full-flow filter change period for the various service applications. The filter element should be changed at the same time the crankcase oil is drained. Filter life is affected by heat and vibration in addition to contaminant filtration. Filter change should not exceed 25,000 miles/500 hours maximum.

TABLE L-4

USED LUBE OIL ANALYSIS GUIDELINES

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown. Characteristics relating to lube oil dilution should trigger corrective action to identify and fix the source(s) of leaks, if these values are realized.

	ASTM Designation	ENGINE SERIES: 2-CYCLE Series 149	2-CYCLE Series 92	2-CYCLE Series 71	2-CYCLE Series 53	4-CYCLE Series 8.2L
		WARNING LIMITS				
Pentane Insolubles, Wt. %	D-893	1.00	1.00	1.00	1.00	1.00
Carbon (Soot) Content Wt. % Max.	TGA †	0.80	0.80	0.80	0.80	2.00
Viscosity at 100°F, SUS	D-445 & D-2161					
% Max. Increase		40.0	40.0	40.0	40.0	40.0
% Max. Decrease		15.0	15.0	15.0	15.0	15.0
Total Base Number (TBN), Min.	D-664	1.00	1.00	1.00	1.00	1.00
Total Base Number (TBN), Min.	D-2896	2.00	2.00	2.00	2.00	2.00
Water Content (Dilution), Vol. %, Max.	D-85	0.30	0.30	0.30	0.30	0.30
Flash Point, °F, Max. Reduction	D-92	40.0	40.0	40.0	40.0	40.0
Fuel Dilution, Vol. %, Max.	—	1.00	2.50	2.50	2.50	2.50
Glycol Dilution, PPM., Max.	D-2982	1000.00	1000.00	1000.00	1000.00	1000.00
Iron Content, PPM., Max.	‡	35	150	150	150	250
Sodium Content, PPM Max. Allowed Over Lube Oil Baseline	‡	50	50	50	50	50
Boron Content, PPM., Max. Allowed Over Lube Oil Baseline	‡	20	20	20	20	20

† TGA — Thermogravimetric analysis used and recommended by Detroit Diesel. No ASTM procedure designation.

‡ Elemental analyses are conducted using either emission spectographic or atomic absorption instruments. Neither method has ASTM designation.

FREQUENCY OF LUBE OIL SAMPLES FOR ANALYSIS

The interval at which used lube oil samples may be obtained for analysis can be scheduled for the same period as when other preventative maintenance is conducted. For example, in highway truck applications, a sample may be obtained every 10,000 miles when engines are brought in for fuel and coolant filter replacement. (Reference instructions in Detroit Diesel Engine Service Manuals).

USED LUBE OIL ANALYSIS PROGRAM

A used lube oil analysis program is recommended for monitoring the condition of the crankcase oil in all engines.

Primarily, used lube oil analyses indicate the condition of the oil but not necessarily the condition of the engine. *Never tear down an engine based solely on the analysis results obtained from a single used oil sample.* However, the condition of the engine should be investigated using conventional mechanical and/or electronic diagnostic instruments. Frequently, visual inspections are all that is required to detect problem areas related to engine wear. *It is also prudent to obtain another oil sample from the suspected distressed unit for analysis.*

Abnormal concentrations of some contaminants such as diesel fuel, coolant, road salt, or airborne dirt cannot be tolerated for prolonged periods. Their presence will be reflected in accelerated engine wear, which can result in less than optimum engine life. The oil should be changed immediately if any contamination is present in concentrations exceeding the warning limits shown in Table L-4.

Experience in specific engine applications operating specific model engines is a prerequisite for proper interpretation of laboratory used lube oil sample analysis results. It is imperative to remember, in scrutinizing *laboratory used lube oil sample results, that it is the* change in value or deviation from baseline data obtained from the new oil (same brand or mixture of brands) that is significant. This is especially important to remember in investigations such as wear metal analysis, total base number and viscosity determinations.

SULFATED ASH LIMIT

There are no sulfated ash limits imposed on lubricants used in Detroit Diesel 4-cycle engines.

ZINC CONTENT

The zinc content (zinc diorganodithiophosphate) of all low ash (less than 1.000% by weight) lube oils recommended for use in Detroit Diesel 2-cycle and 4-cycle engines shall be a minimum of 0.07% by weight. EMD oils are not recommended for use in Detroit Diesel 4-cycle engines where ambient temperatures are below 50°F (10°C).

Some specific high ash oils (2.500% by weight maximum) do not contain zinc additives. These oils may be used where diesel fuels with greater than 0.50% by weight sulfur content are continuously used.

MIL-L-46167 ARCTIC LUBE OILS FOR NORTH SLOPE AND OTHER EXTREME SUB-ZERO OPERATIONS

Lubricants meeting this specification are used in Alaska and other extreme sub-zero locations. Generally, they may be described as 5W-20 multigrade lubricants made up of synthetic base stock and manifesting low volatility characteristics. Although they have been used successfully in some severe cold regions, Detroit Diesel Allison does not consider their use as desirable as the use of SAE-40 or SAE-30 oils with auxiliary heating aids. For this reason, they should be considered only where engine cranking is a severe problem and auxiliary heating aids are not available on the engine.

SYNTHETIC OILS

Synthetic lubricants may be used in Fuel Pincher engines provided the specified oil performance levels shown under RECOMMENDATION are met.

MISCELLANEOUS FUEL AND LUBRICANT INFORMATION

ENGINE OIL CLASSIFICATION SYSTEM

The American Petroleum Institute (API), the Society of Automotive Engineers (SAE), and the American Society for Testing and Materials (ASTM) jointly have developed the present commercial system for designating and identifying motor oil classifications. The table in this section shows a cross-reference of current commercial and military lube oil identification and specification systems.

CROSS-REFERENCE OF LUBE OIL CLASSIFICATION SYSTEM

API CODE LETTERS	COMPARABLE MILITARY OR COMMERCIAL INDUSTRY SPECIFICATION
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (See Note Below)
CD	MIL-L-45199B (Series 3)
‡	MIL-L-46152 (Supersedes MIL-L-2104B Military Only)
□	MIL-L-2104C (Supersedes MIL-L-45199B for Military Only)
SA	None
SB	None
SC	Auto Passenger Car 1964 MS Oils - Obsolete System
SD	Auto Passenger Car 1968 MS Oils - Obsolete System
SE	Auto Passenger Car 1972 MS Oils - Obsolete System
SF	Auto Passenger Car 1980 Production

‡ Oil performance meets or exceeds that of CC and SE oils.

□ Oil performance meets or exceeds that of CD and SC oils.

NOTE: MIL-L-2104B lubricants are obsolete for military service applications only.
MIL-L-2104B lubricants are currently marketed and readily available for commercial use.

Consult the following publications for complete descriptions:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.
2. Federal Test Method Standard 791a.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled *EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines.* The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

Upon request, the Detroit Diesel Allison Regional Office will counsel with customers in selecting a lubricating oil that will be suitable for their specific needs.

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpt has been taken from a policy statement of General Motors Corporation:

"It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. It is accordingly contrary to the policy of General Motors to recommend the regular and continued use of supplementary additives in fuels and lubricants."

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NOTICE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations may not be within the coverage of the warranty.

COOLANT SPECIFICATIONS

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

COOLANT REQUIREMENTS

Coolant solutions used in Detroit Diesel engines must meet the following basic requirements:

1. Provide for adequate heat transfer.

2. Provide a corrosion-resistant environment within the cooling system.

3. Prevent formation of scale or sludge deposits in the cooling system.

4. Be compatible with the cooling system hose and seal materials.

5. Provide adequate freeze protection during cold weather operation and boil-over protection in hot weather.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When freeze protection is required, a solution of suitable water and an antifreeze containing adequate inhibitors will provide a satisfactory coolant. Ethylene glycol-based antifreeze solutions are recommended for year-round use in Detroit Diesel engines.

WATER

Whether of drinking quality or not, any water will produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides and sulfates, total hardness and dissolved solids.

Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination of these. Chlorides, sulfates, magnesium and calcium are among

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE 1

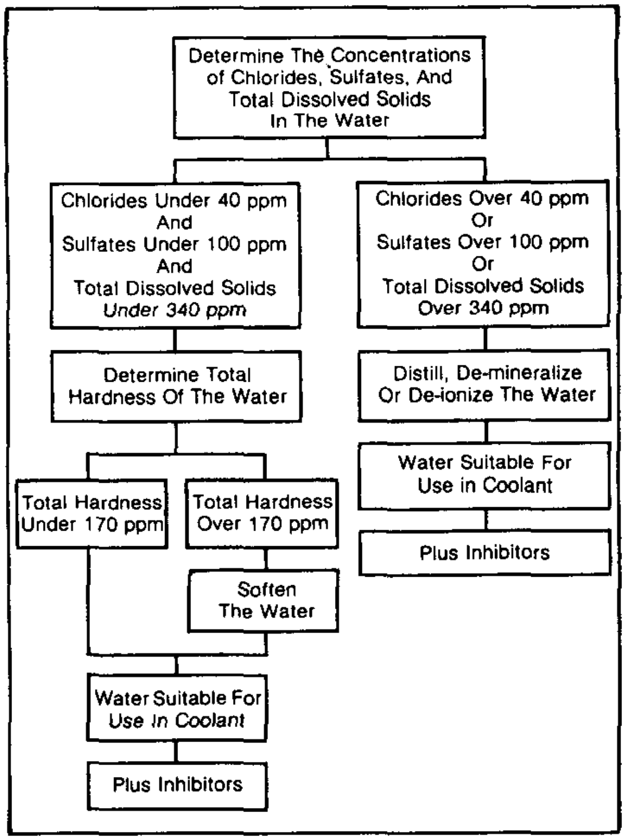


TABLE 2

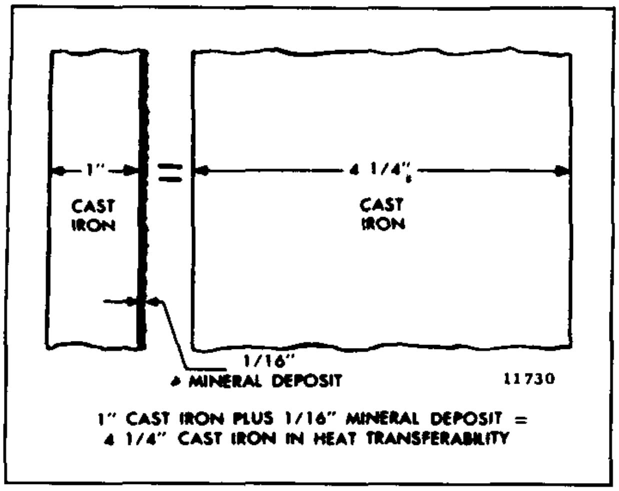


Fig. 1 - Heat Transfer Capacity

the materials which make up dissolved solids. Water within the limits specified in Table 1 is satisfactory as an engine coolant when proper inhibitors are added. The procedure for evaluating water intended for use in a coolant solution is shown in Table 2.

CORROSION INHIBITORS VITAL

A corrosion inhibitor is a water-soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. (Soluble oil is not recommended as a corrosion inhibitor). Depletion of all types of inhibitors occurs through normal operation. Therefore, strength levels must be maintained by adding inhibitors as required after testing the coolant.

The importance of a properly inhibited coolant cannot be overstressed. A coolant which has insufficient inhibitors, the wrong inhibitors, or-worse-no inhibitors at all invites the formation of rust and scale deposits within the cooling system. Rust, scale, and mineral deposits can wear out water pump seals and coat the walls of the cylinder block water jackets and the outside walls of the cylinder liners. As these deposits build up, they insulate the metal and reduce the rate of heat transfer. For example, a 1/16" deposit of rust or scale on 1" of cast iron is equivalent to 4-1/4" of cast iron in heat transferability (Fig. 1).

An engine affected in this manner overheats gradually over a period of weeks or months. Liner scuffing, scoring, piston seizure and cylinder head cracking are the inevitable results. An improperly inhibited coolant can also become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If sufficient coolant accumulates on top of a piston, a hydrostatic lock can occur while the engine is being started. This, in turn, can result in a bent connecting rod. An improperly inhibited coolant can also contribute to *cavitation erosion.* Cavitation erosion is caused by the collapse of bubbles (vapor pockets) formed at the coolant side of an engine component. The collapse results from a pressure differential in the liquid caused by the vibration of the engine part. As bubbles collapse, they form pin points of very high pressure. Over a period of time, the rapid succession of millions of tiny bursting bubbles can wear away (erode) internal engine surfaces.

Components such as fresh water pump impellers and cylinder liners are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy, and holes can develop completely through them.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used *water* system corrosion inhibitors. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should *not* be used in antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages reducing the heat transfer rate (Fig. 1) resulting in engine overheating. Engines which have operated with a chromate- inhibited water must be chemically cleaned before the addition of antifreeze. A commercial heavy-duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1.25% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2.50% concentration raises fire deck temperature up to 15%. *Soluble oil is not recommended as a corrosion inhibitor.*

Non-Chromates

Non-chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water-and-antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical compounds which provide corrosion protection, pH control and water- softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors Vital*. pH control is used to maintain an acid-free solution. The water-softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry inhibitor additives and as integral parts of antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

High chloride coolants will have a detrimental effect on the water-softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride-content solutions.

Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

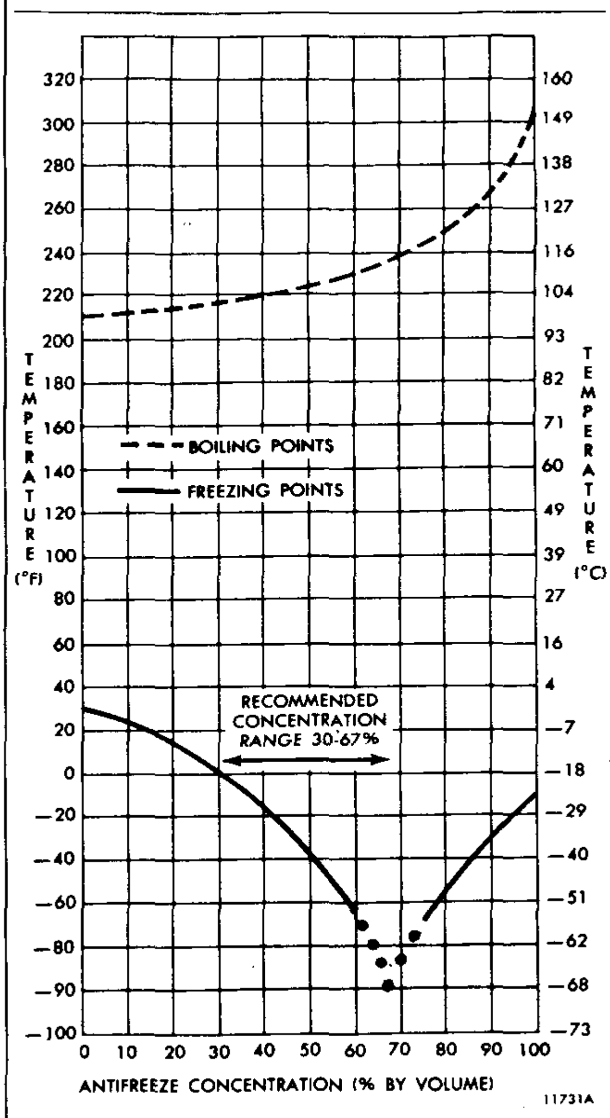


Fig. 2 - Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

Non-chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or water-and-antifreeze solutions and provide corrosion protection, pH control and water softening. Some non-chromate inhibitor systems offer the additional advantage of a simple on-site test to determine protection level. Since they are added directly to the coolant, they require no additional hardware or plumbing.

All inhibitors become depleted through normal operation and additional inhibitor must be added to the

coolant, as required to maintain original strength levels. Always follow the supplier's recommendations on inhibitor usage and handling.

TEST METHODS

Test kits and test strips are commercially available to check engine coolant for corrostion inhibitor strength level. Coolant should be tested to determine the need for corrosion inhibitor supplements and the amount required. Do not use one manufacturer's test strips to measure the chemical content of another's antifreeze and/or inhibitors. Always follow the manufacturer's recommended test procedures.

ANTIFREEZE

When freeze protection is required, an antifreeze meeting GM specification 1899M must be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required on initial fill if a minimum antifreeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Concentrations over 67% adversely affect freeze protection and heat transfer rates (Fig. 2).

Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base anitfreeze is not recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point. Methoxy propanol base antifreeze is not recommended for use in Detroit Diesel engines due to the presence of fluoroelastomer seals in the cooling system.

Before installing ethylene glycol base antifreeze in a unit that has previously operated with methoxy propanol, the entire cooling system should be drained, flushed with clean water, and examined for rust, scale contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commerical grade heavy-duty descaler.

The inhibitors in antifreeze solutions should be replenished with a non-chromate corrosion inhibitor supplement when indicated by testing the coolant. Engine coolant should be checked at approximately 500 hour to 20,000 mile intervals.

Antifreeze solutions should be used year-round to provide freeze protection in the winter, boil-over protection in the summer and a stable environment for seals and hoses in the cooling system of the engine.

Sealer Additives

The use of antifreeze containing sealer additives or the addition of sealer additives to any type coolant in Detroit Diesel engines is not recommended due to plugging possibilities throughout various areas of the cooling system, including cooling system bleed holes and water pump drain holes.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which permit operation at temperatures higher than non-pressurized systems. It is essential that these systems be kept clean and leak-free, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be properly maintained.

Always maintain engine coolant at the proper level. A low coolant level allows the water pump to mix air with the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing normal heat transfer. An abnormally low coolant level can cause the water pump to become air-bound, a condition in which it works feverishly but pumps nothing. Without proper heat transfer, silicone elastomer head-to-block water hole seals can deteriorate and cylinder components can expand so that pistons rapidly cut through the lubricant on the liner walls. Scuffing and piston seizure may follow.

> **CAUTION:** Use extreme care when removing a radiator pressure-control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

An engine may contain the correct amount of properly inhibited coolant, but still fail to adequately cool the engine. In cases where this occurs, other causes of low coolant flow, either engine or cooling system related, should be investigated.

1. Always use a properly inhibited coolant.

2. Do not use soluble oil.

3. Maintain the prescribed inhibitor strength.

4. Always follow the manufacturer's recommendations on inhibitor usage and handling.

5. If freeze protection is required, use a solution of water and antifreeze meeting GM specification 1899M.

6. Reinhibit antifreeze with a non-chromate inhibitor system.

7. Do not use a chromate inhibitor with antifreeze.

8. Do not use methoxy propanol base antifreeze.

9. Do *not mix* ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Do not use sealer additives or antifreeze containing sealer additives.

11. Do not use methyl alcohol base antifreeze.

12. Use extreme care when removing the radiator pressure-control cap.

13. Do not add inhibitor supplements to new antifreeze solutions.

14. Use an antifreeze solution year-round for freeze and over-boil protection. Seasonal changing of coolant from an antifreeze solution to an inhibitor/water solution is *not recommended.*

SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

To tune up an engine completely, perform all of the adjustments given below. It is desirable to tune the engine cold; however, if it is necessary to perform the tune-up at engine operating temperature, we have provided the specifications to do so.

> **CAUTION:** Before starting an engine after an engine speed control adjustment, or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no-fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

> **NOTE:** If the governor does not have a stop lever it will be necessary to install a suitable stop lever for use during an engine tune-up.

An electric shutdown solenoid (Fig. 1) is mounted on the engine governor. The solenoid must be removed from the governor prior to connecting the governor linkage to the rack control shaft or engine overspeed may occur.

This precaution is necessary because the solenoid is designed to hold the fuel shutdown in the stop position at all times except when the solenoid is energized. If the injector racks are held in the full-fuel position and connected to the governor while the shutdown is in the stop position, the injector will be locked at full rack (maximum fuel).

Tune-Up Sequence

1. Adjust the intake and exhaust valve clearances (Section 14.1).

2. Adjust injector heights to agree with the dimensions on the timing label (Section 14.2).

3. Position the injector rack control levers (Section 14.3).

4. Adjust the static governor gap (Section 14.3).

5. Connect the injector control rack to the governor (Section 14.3).

6. Back out the buffer screw (Section 14.3.2).

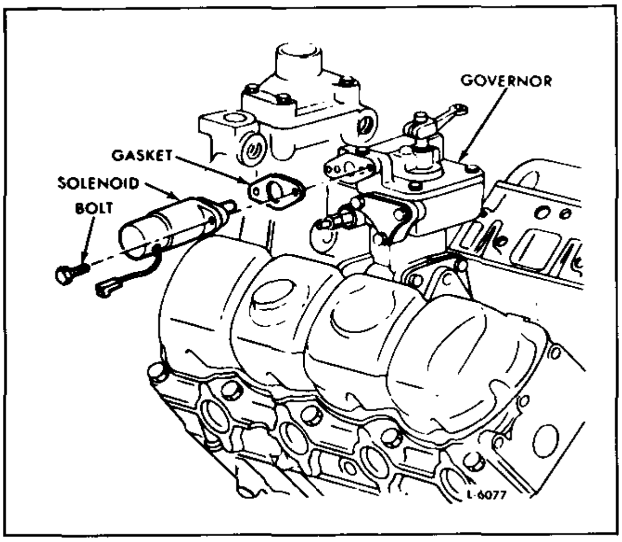


Fig. 1 - Shutdown Solenoid on Governor

7. Back out the idle screw (Section 14.3.2).

8. Set the high speed spring adjusting nut (Section 14.3.2).

9. Adjust the idle (Section 14.3.2).

10. Adjust maximum no load rpm (Section 14.3.2).

11. Check idle rpm and adjust if necessary (Section 14.3.2).

12. Adjust the buffer screw (Section 14.3.2).

1981 CERTIFIED AUTOMOTIVE CONFIGURATIONS

1981 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	V8-8.2N	V8-8.2T
Injectors (a)	4A53	4C65
Maximum Full Load Speed (a)	3000	3000
Minimum Full Load Speed	3000	3000
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
Injector Timing	43.8 (i)	44.75 (i)
Throttle Delay Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.

1981 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	V8-8.2NC	V8-8.2TC
Injectors (a)	4A53	4B65
Maximum Full Load Speed (a)	3000	3000
Minimum Full Load Speed	3000	3000
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
Injector Timing	44.45 (i)	44.75 (i)
Throttle Delay Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.

1981 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
V8-8.2N	4A53	165 @ 3000	350 @ 1200
V8-8.2T	4C65	205 @ 3000	430 @ 1700
V8-8.2NC (California)	4A53	165 @ 3000	350 @ 1200
V8-8.2TC (California)	4B65	205 @ 3000	430 @ 1700
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS 85°F (29.4°C) – AIR INLET TEMPERATURE 29.00 IN. HG (98.19 kPa) – BAROMETER (DRY)			

NOTES:

DNA – Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(i) Top dead center timing expressed in millimeters. For base circle timing, see injector timing label on rocker cover.

1982 CERTIFIED AUTOMOTIVE CONFIGURATIONS

1982 FEDERAL CERTIFIED AUTOMOTIVE ENGINE CONFIGURATIONS

FAMILIES	8.2	8.2T
INJECTORS	4A53 4A40 B	4C65 4A53 BB
MAX. FULL LOAD SPEED	3000	3000
MIN. FULL LOAD SPEED	2800 B	2800 BB
MIN. IDLE SPEED	700	700
GEAR TR. TIMING	Std.	Std.
INJECTOR TIMING	4A53-43.8MM 4A40-44.25MM	4C65-44.75MM 4A53-43.8MM
THROTTLE DELAY SETTING	DNA	DNA
LINER PORT HGHT	DNA	DNA
LINER PART NO.	DNA	DNA
TURBO-CHARGER A/R	DNA	3LM-4.03 4.41 sq. in.
TURBO-CHARGER P/N	DNA	8920678
BLOWER DR. RATIO	DNA	DNA
BLOWER PART NO.	DNA	DNA
COMP. RATIO	18.3:1	16.9:1
EXHAUST VALVE P/N	DNA	DNA
CERT. LABEL NO.	1487-341	1487-343 1487-344

B 2800 RPM MAX. WITH 4A 40 INJECTORS
BB 2800 RPM MAX. WITH 4A 53 INJECTORS
DNA DOES NOT APPLY

1982 CALIFORNIA CERTIFIED AUTOMOTIVE ENGINE CONFIGURATIONS

FAMILIES	V8-8.2	V8-8.2T
Injectors	4A53	4C65
Maximum Full Load Speed	3000	3000
Minimum Full Load Speed	2800	3000
Minimum Idle Speed	700	700
Gear Train Timing	Std	Std
Injector Timing	44.45MM	44.75MM
Throttle Delay Setting	DNA	DNA
Liner Port Height	DNA	DNA
Liner Part Number	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In
Turbocharger Part Number	DNA	8920678
Blower Drive Ratio	DNA	DNA
Blower Part Number	DNA	DNA
Compression Ratio	18.3:1	16.9.1
Exhaust Valve Part Number	DNA	DNA

DNA DOES NOT APPLY

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
V8-8.2N	4A40 4A53	130 @ 2800 165 @ 3000	318 @ 1000 350 @ 1200
V8-8.2T (Fed/Calif)	4C65	205 @ 3000	430 @ 1700
V8-8.2N & T (Fed/Exp)	4A53	160 @ 2800 160 @ 2800	T 369 @ 1400 N 350 @ 1200
V8-8.2NC (California)	4A53	165 @ 3000 160 @ 2800	350 @ 1200 350 @ 1200

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

1983 AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	V8-8.2N	V8-8.2T
Injectors (a)	4A40 4A53	4A53 4C65
Maximum Full Load Speed (a)	3000 (j)	3000 (k) (l)
Minimum Full Load Speed	2800	2600
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
Injector Timing	4A40-44.25 4A53-43.8 (i)	4A53-43.8 4C65-44.75 4C65-44.25 (i)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-4.03 4.41 Sq. In.
Turbocharger Part No.	DNA	8920678
Blower Drive Ratio	DNA	DNA
Blower Part No.	DNA	DNA
Compression Ratio	18.3:1	16.9:1
Exhaust Valve Part No.	DNA	DNA
Liner Part No.	DNA	DNA
Liner Port Height	DNA	DNA

NOTES:

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(i) Top dead center timing expressed in millimeters. For base circle timing see injector timing label on rocker cover.

(j) 2800 Max. FL RPM with 4A40 Injector.

(k) 2800 Max. FL RPM with 4C65 injector at 44.25 Injector Timing.

(l) 2800 Max. FL RPM with 4A53 Injector.

CALIFORNIA

ENGINE FAMILIES	V8-8.2NC	V8-8.2TC
Injectors (a)	4A53	4C65
Maximum Full Load Speed (a)	3000	3000
Minimum Full Load Speed	2800	3000
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std
Injector Timing	44.45 (i)	44.75 (i)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.
Turbocharger Part No.	DNA	8920678
Blower Drive Ratio	DNA	DNA
Blower Part No.	DNA	DNA
Compression Ratio	18.3:1	16.9:1
Exhaust Valve Part No.	DNA	DNA
Liner Port Height	DNA	DNA
Liner Part No.	DNA	DNA

NOTES:

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(i) Top dead center timing expressed in millimeters. For base circle timing see injector timing label on rocker cover.

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
V8-8.2N (Fed.)	4A40 4A53 4A53	130 @ 2800 160 @ 2800 165 @ 3000	318 @ 1000 350 @ 1200 350 @ 1200
V8-8.2NC (California)	4A53	165 @ 3000	350 @ 1200
V8-8.2T (Fed.)	4A53 4C65	156 @ 2600 200 @ 2800	375 @ 1400 440 @ 1700
V8-8.2T (Fed/Exp)	4A53	160 @ 2800	375 @ 1400
V8-8.2T (Fed/Calif)	4C65	205 @ 3000	430 @ 1700
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS			

1984 AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	V8-8.2N	V8-8.2T
Injectors (a)	4A40 4B45 4A53	4A53 4C65
Maximum Full Load Speed (a)	2800	2800
Minimum Full Load Speed	2800	2800 4A53-2600
Minimum Idle Speed	700	700
Gear Train Timing	Std	Std.
Injector Timing	4A40-44.25 4B45-43.80 4A53-43.80 (i)	4A53-43.80 4C65-44.25 (i) (k)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.

CALIFORNIA

ENGINE FAMILIES	V8-8.2NC	V8-8.2TC
Injectors (a)	4B45 4B55	4E67
Maximum Full Load Speed (a)	2800	2800
Minimum Full Load Speed	2800	2800
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
Injector Timing	4B45-44.45 4B55-44.25 (i)	44.75 (i)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.

NOTES:

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(i) Top dead center timing expressed in millimeters. For base circle timing see injector timing label on rocker cover.

(k) Repower Turbocharged units are certified to 3,000 RPM. See Emission Label. Injector Timing: 4C65 - 44.75.

1984 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
V8-8.2N (Fed.)	4A40 4B45 4A53	130 @ 2800 145 @ 2800 165 @ 2800	318 @ 1000 330 @ 1200 354 @ 1200
V8-8.2NC (California)	4B45 4B55	145 @ 2800 165 @ 2800	330 @ 1200 370 @ 1200
V8-8.2T (Fed.)	4A53 4A53 4C65	160 @ 2600 165 @ 2800 205 @ 2800	383 @ 1400 383 @ 1400 442 @ 1700
V8-8.2TC (California)	4E67	200 @ 2800	440 @ 1700
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J 1349 CONDITIONS			

1985 AUTOMOTIVE CONFIGURATIONS

FEDERAL

ENGINE FAMILIES	V8-8.2N	V8-8.2T
Injectors (a)	4A40 4B45 4A53	4H60 4A53 4C65 4J60 4B75
Maximum Full Load Speed (a)	2800	2800
Minimum Full Load Speed	2800	2800 4J60-2600
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
Base Circle Injector Timing	4A40-47.80 4B45-47.35 4A53-47.35	4A53-47.35 4H60-47.80 4J60-47.80 4C65-47.80 4B75-47.35 (k)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.
Closed Crankcase Breather System	Required	DNA

CALIFORNIA

ENGINE FAMILIES	V8-8.2N	V8-8.2T
Injectors (a)	4B45 4B55	4E67 4K60
Maximum Full Load Speed (a)	2800	2800
Minimum Full Load Speed	2800	2800 4K60-2600
Minimum Idle Speed	700	700
Gear Train Timing	Std.	Std.
T.D.C. Injector Timing	4B45-44.45 4B55-44.25 (i)	44.75-4E67 44.45-4K60 (i)
Throttle Delay Setting	DNA	DNA
Modulator Setting	DNA	DNA
Turbocharger A/R	DNA	3LM-403 4.41 Sq. In.
Closed Crankcase Breather System	Required	DNA

NOTES:

All injector timings are expressed as <u>base circle</u> except California certified and repower turbo units certified at 3,000 rpm with 4C65 injectors.

DNA Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(i) Top dead center timing expressed in millimeters. For base circle timing, see injector timing label on rocker cover.

(k) Repower turbocharged units are certified to 3,000 rpm. See emission label.
T.D.C. Injector Timing: 4C65-44.75.

FUEL INJECTORS

1985 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB—FT)
V8-8.2N (Federal)	4A40 4B45 4A53	130 @ 2800 145 @ 2800 165 @ 2800	318 @ 1000 330 @ 1200 354 @ 1200
V8-8.2NC (California)	4B45 4B55	145 @ 2800 165 @ 2800	330 @ 1200 370 @ 1200
V8-8.2T (Federal)	4J60 4A53 4H60 4C65 4B75	165 @ 2600 165 @ 2800 190 @ 2800 205 @ 2800 230 @ 2800	418 @ 1400 383 @ 1400 434 @ 1500 442 @ 1700 510 @ 1700
V8-8.2TC (California)	4K60 4E67	165 @ 2600 200 @ 2800	405 @ 1400 440 @ 1700
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J1349 CONDITIONS			

VALVE CLEARANCE ADJUSTMENT

Accurate adjustment of the clearance between the end of the rocker arm and the valve is very important if maximum performance and economy are to be obtained.

CAUTION: Be sure that the injectors are in a no-fuel position before barring the engine as personal injury could result.

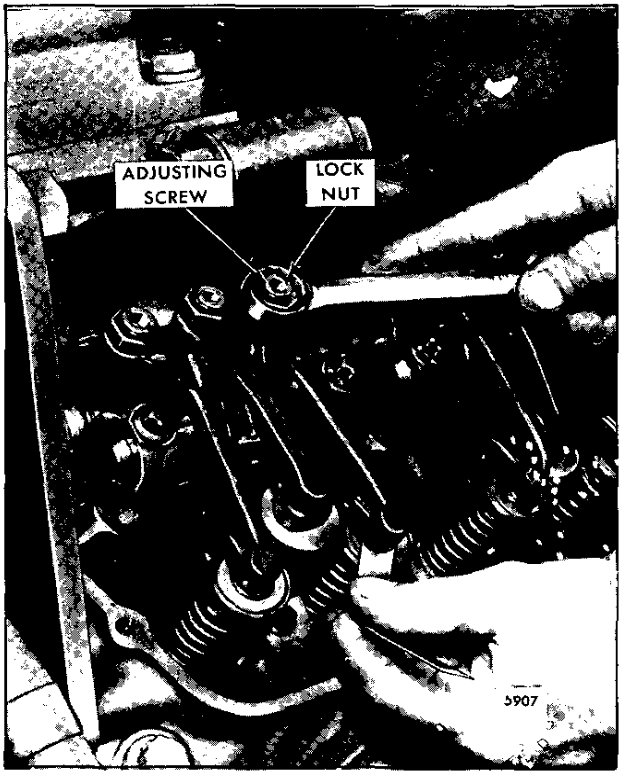


Fig. 1 - Adjusting Valve Clearance

NOTE: When a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

Valve Clearance Specifications		
	Intake MM/(Inch)	Exhaust MM/(Inch)
Hot	0.28/(0.011)	0.31/(0.012)
Cold 38° C. (100° F) or less	0.31/(0.012)	0.36/(0.014)

Valve clearance is adjusted by means of an adjusting set screw and locknut (Fig. 1) located at the push rod end of the rocker arm. The procedure is to first turn the crankshaft clockwise until the piston is near top dead center compression and the injector rocker arm is moving downward. Then insert the feeler gage between the end of the appropriate valve stem and rocker arm, loosen the locknut, and turn the adjusting set screw until the gage is a snug fit between the valve stem and the rocker arm. The adjustment is then secured by tightening the locknut. Refer to Chart.

All of the injectors and valves can be timed in firing order sequence (1, 8, 4, 3, 6, 5, 7, 2) during two complete revolutions of the crankshaft (clockwise rotation as viewed from the front).

To perform the valve adjustment during a base circle tune-up procedure, continue to Section 14.2.

FUEL INJECTOR TIMING (Base Circle)

It is essential that the valves and injectors be in correct adjustment at all times for the engine to operate properly. One controls engine breathing; the other controls fuel delivery to the cylinders.

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body. Refer to Figs. 1 and 2. All of the injectors and valves can be timed in firing order sequence (1, 8, 4, 3, 6, 5, 7, 2) during two complete revolutions (clockwise rotation as viewed from the front) of the crankshaft.

The "Base Circle" of a cam lobe is any point on that lobe at which a cam follower is at rest (no lift has occured). Refer to Fig. 3.

Precision injector timing is set on the "lift ramp" of the cam during manufacture of the engine to meet exhaust emission requirements. Any subsequent servicing of the injectors requires a predetermined base circle injector height (which is derived from the precision method) for each cylinder position. These specific base circle heights have been measured and recorded on the timing label during manufacture of each individual engine and the label is affixed to the left rocker cover. Unless a major engine component (crankshaft, camshaft, timing gears or cylinder block) is changed, the original timing label may be used to perform an engine tune-up. When any of the above engine components are changed in an engine overhaul, a precision, top dead center, timing procedure must be performed (refer to Section 14.2.1).

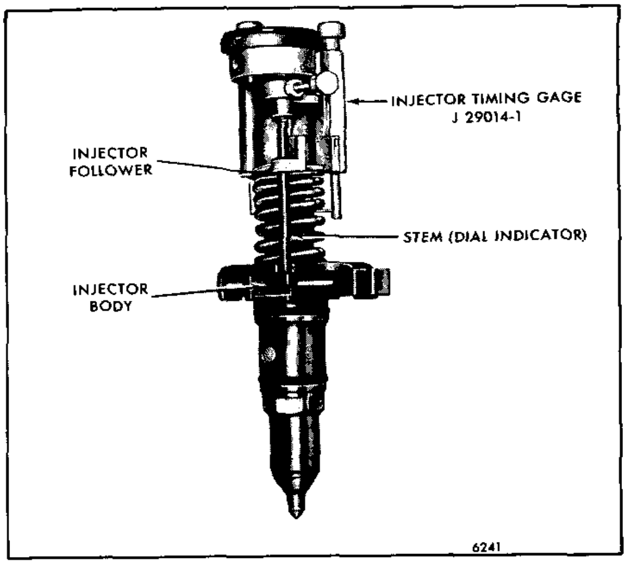


Fig. 2 - Timing Gage Installed on Injector

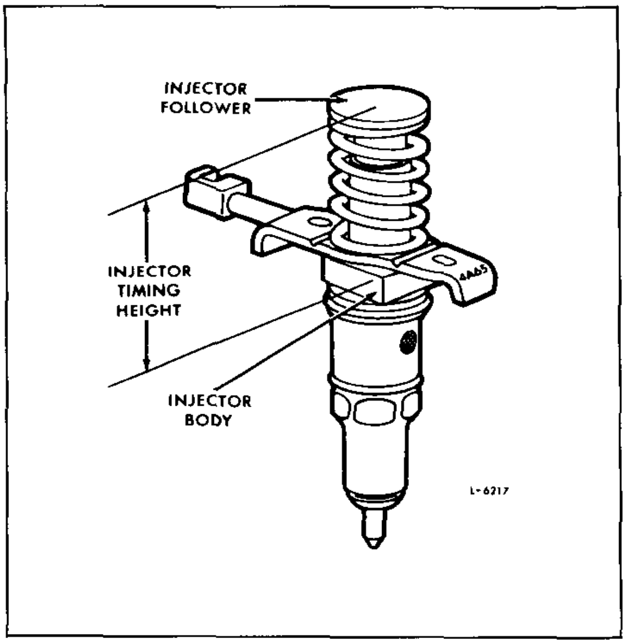


Fig. 1 - Injector Timing Height

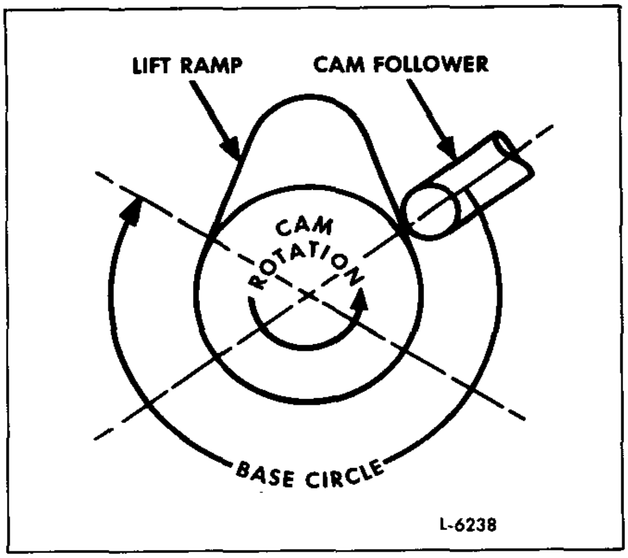


Fig. 3 - Base Circle

Injector Timing Gage

Injector timing gage J 29014-1 (Fig. 4) has been designed for timing the engine using the base circle method or the precision, top dead center timing procedure. When timing by the base circle method, use the black numbers on the dial face and the lower step of the master.

NOTE: Do not attempt to remove the stem from the dial indicator. The stem has been permanently attached and will cause internal damage to the indicator if turned.

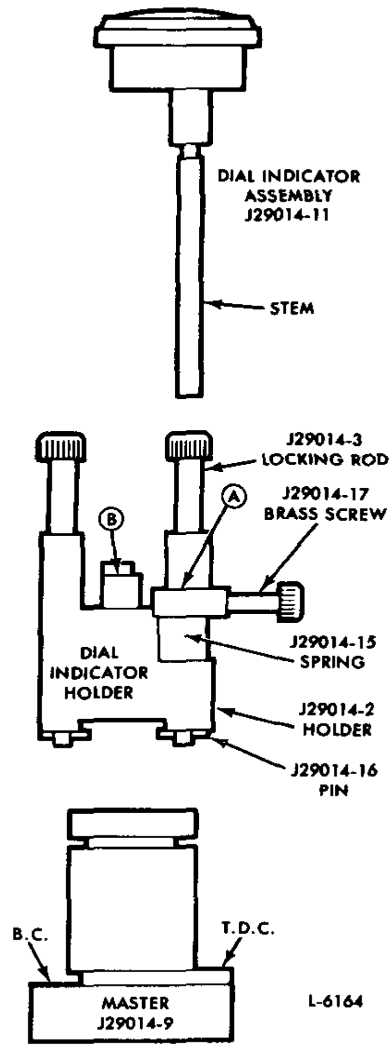


Fig. 4 - Injector Timing Gage

Calibrating the Injector Timing Gage for the Base Circle Method

1. Loosen the brass locking screw on the side of the dial indicator holder and place the holder on top of the master. Make sure the indicator stem is located on the LOWER step of the master.

2. Lock the holder in place by pressing the spring loaded rods and rotating until the pins engage the groove in the master. The slots in the top of the rods will point at each other when properly positioned.

3. While rotating the dial indicator, (to clear position "B") push down to lowest position in the holder, position "A", Fig. 4, and lock into place with the brass screw.

4. To calibrate, hold the dial indicator body firmly and rotate the dial face by turning the black ring. Position the word "CAL" directly under the pointer. As the gage is removed from its master, you should observe counterclockwise pointer movement of 1/2 to 3/4 of a turn on the dial.

5. The gage is now calibrated to measure a base circle setting.

Base Circle Timing Procedure

With a calibrated injector timing gage (J 29014-1) proceed as follows:

CAUTION: Be sure that the injectors are in a no-fuel position before barring the engine as personal injury could result.

NOTE: When a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

1. Rotate the crankshaft clockwise until the No. 1 injector rocker arm is at the top of its stroke (on the cam base circle).

2. Install gage J 29014-1 and bar the engine over until the No. 1 injector follower descends between 0.5 to 1.0 mm (0.020" to 0.040").

NOTE: The injector's downward travel can exceed the dial movement capability of the gage J 29014-1. Remove the gage from the injector prior to barring the engine any further than described above.

3. Injector timing can now be set on cylinders 3, 4, 6 and 8 as per the dimensions found on the timing label.

Check the calibration of the gage after each injector setting is completed. Perform steps a, b and c on cylinders 3, 4, 6 and 8 as follows:

a. Loosen the injector rocker arm adjusting screw locknut and back out the adjusting screw until approximately three full threads are showing.

b. Turn the rocker arm adjusting screw back in until the timing label dimension is obtained.

c. Tighten the locknut and recheck the reading on the gage.

Valve Adjustments

At this point, valve clearance can now be adjusted (at 90° intervals) in the clockwise firing order sequence on cylinders 1, 8, 4 and 3.

> **CAUTION:** Be sure that the injectors are in a no-fuel position before barring the engine as personal injury could result.

Refer to specifications in the chart and proceed as follows:

Valve Clearance Specifications		
	Intake MM/(Inch)	Exhaust MM/(Inch)
Hot	0.28/(0.011)	0.31/(0.012)
Cold 38° C. (100° F) or less	0.31/(0.012)	0.36/(0.014)

> **NOTE:** When a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

1. Set valves on cylinder 1 (the injector had begun its downward travel).

2. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 8.

3. Set valves on cylinder No. 8.

4. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 4.

5. Set valves on cylinder No. 4.

6. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 3.

7. Set valves on cylinder No. 3.

Base Circle Injector Timing (Cont.)

1. Install gage J 29014-1 and bar the engine clockwise until No. 6 injector follower descends between 0.5 to 1.0 mm (0.020" to 0.040").

> **NOTE:** The injector's downward travel can exceed the dial movement capability of the gage J 29014-1. Remove the gage from the injector prior to barring the engine any further than described above.

2. Injector timing can now be set on cylinders 1, 2, 5 and 7 as per the dimensions found on the timing label. Check the calibration of the gage after each setting is completed.

Valve Adjustments (Cont.)

At this point, valve clearance can now be adjusted (at 90° intervals) in the clockwise firing order sequence on cylinders 6, 5, 7 and 2.

> **NOTE:** When a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

1. Set valves on cylinder No. 6 (the injector had begun its downward travel).

2. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 5.

3. Set valves on cylinder No. 5.

4. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 7.

5. Set valves on cylinder No. 7.

6. Bar the engine 90° clockwise and observe for injector movement on cylinder No. 2.

7. Set valves on cylinder No. 2.

At this point in the tune-up procedure all of the

injectors and valves have been adjusted. Refer to Section 14.3 for the procedure for setting the injector rack controls.

FUEL INJECTOR TIMING (Precision T.D.C.)

Whenever a crankshaft, camshaft, cylinder block or gear train is replaced, any previously determined injector timing heights are no longer valid. To maintain conformance to Federal E.P.A. and California emission specifications, the former injector timing height sticker or label on the rocker cover must be removed and replaced with dimensions determined by performing the precision T.D.C. timing procedure.

Procedure Outline

1. Remove cylinder head.

2. Install tool J 29011-A (Slug Gage).

3. Install tool J 29139 (Timing Pin and Guide).

4. Remove tool J 29011-A (Slug Gage).

5. Install cylinder head.

6. Adjust injector heights with their respective cylinders positioned at T.D.C.

7. Measure and record injector heights at their respective base circle positions.

8. Remove tool J 29139 (Timing Pin and Guide) and complete the engine tune-up.

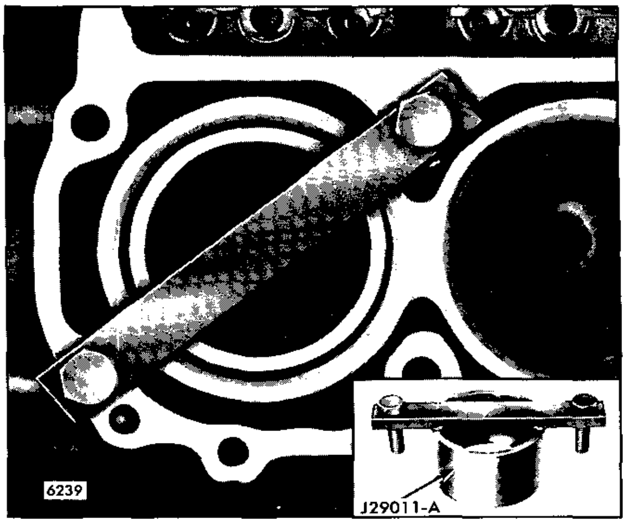


Fig. 1 - J-29011-A Installed

Remove Cylinder Head

Remove the cylinder head to establish the precision top dead center with tool J 29011-A (Slug Gage).

> **NOTE:** When a wrench or barring tool is used on the crankshaft at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

> **CAUTION:** Be sure the injectors are in a no-fuel position before barring the engine as personal injury could result. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short. Tag each lead to ensure correct connections.

Position the No. 1 piston so that it is beginning its compression stroke.

Install Slug Gage

Install tool J 29011-A (Slug Gage) in cylinder No. 8 (right bank) or cylinder No. 5 (left bank). Snug the bolts to secure the tool into position. Bar the engine clockwise until the piston is firmly against the tool. At this point the No. 1 piston is at T.D.C. (Fig. 1).

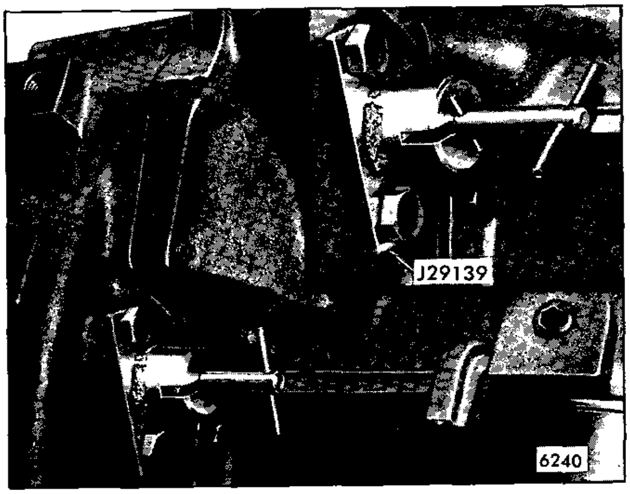


Fig. 2 - J 29139 Installed

Install Timing Pin and Guide

Remove the dust cover in the flywheel housing and install tool J 29139 (Timing Pin and Guide) with attaching bolts loose. Insert the timing pin into the flywheel (the flywheel has been machined in four (4) places at 90° from each other to allow timing pin engagement). With the pin engaged, secure the tool in place by tightening the attaching bolts (Fig. 2).

Remove Slug Gage

Remove tool J 29011-A (Slug Gage) and install cylinder head. Do not remove the timing pin and guide.

Adjust Injectors at T.D.C.

1. Calibrate the Injector Timing Gage J 29014-1 for top dead center readings (red numbers on the dial face). Refer to Section 14.2 and perform the same calibration procedure, except: use the T.D.C. step of the master and not the B.C. step.

2. Back out all the injector rocker arm adjusting screws (do not remove).

3. Beginning at No. 1 cylinder, place the calibrated timing gage J 29014-1 on top of the injector follower so that the dial indicator stem rests on the projecting injector body ledge as shown in Fig. 2 in Section 14.2. A good indication that the No. 1 cylinder is on it's compression stroke, is the No. 3 intake valve will be open.

4. Adjust the injector rocker arm adjusting screw and tighten the locknut so that the dial indicator reading agrees with the chart. It is convenient to adjust the valves at the respective cylinders before proceeding to the next injector setting.

5. Disengage the timing pin from flywheel (DO NOT disturb the attaching bolts) and bar the engine clockwise slightly (a couple inches of flywheel movement). Allow the timing pin to drag on the flywheel (via its spring tension), and continue barring the engine over slowly (clockwise). When the pin engages with the flywheel, (approximately 90° of rotation) the No. 8 injector can be adjusted. Be sure to check the calibration of the dial indicator prior to adjusting each injector.

6. Continue this procedure in firing order sequence (1, 8, 4, 3, 6, 5, 7, 2) until all injectors have been set.

Engine Family	TDC Injector Timing Setting
50 State Turbo Engine	44.75 mm
California N.A.	44.45 mm
49 State N.A.	43.80 mm

Measure and Record Base Circle Timing Heights

1. Calibrate the injector timing gage J 29014-1 for base circle readings (black numbers on the dial face). Refer to Section 14.2 for complete instructions, if necessary.

2. Install gage J 29014-1 and bar the engine over (clockwise) until the No. 1 injector follower descends between 0.5 and 1.0 mm (0.020" to 0.040"). The injector's downward travel can exceed the dial movement capability of the gage J 29014-1. Remove the gage from the injector prior to barring the engine any further than described above.

3. Place gage J 29014-1 on the No. 3 injector. The reading on the timing gage is the new base circle timing height. Record this reading on an injector timing label (Fig. 3).

4. Repeat step 3 for base circle injector readings at positions 4, 6 and 8. Check the calibration of the dial prior to each reading.

5. Install gage J 29014-1 and bar the engine over (clockwise) until the No. 6 injector follower descends between 0.5 and 1.0 mm (0.020" to 0.040"). The injector's downward travel can exceed the dial movement capability of the gage J 29014-1. Remove the gage from the injector prior to barring the engine any further than described above.

6. Base circle readings may now be taken and recorded on the base circle timing label, at cylinders 1, 2, 5 and 7 (Fig. 3). Check the calibration of the gage after each reading has been taken (same as steps 3 and 4).

Attach Base Circle Timing Label

Attach the completed timing label to the left rocker cover. At this point in the procedure, the following have been completed.

1. The pistons' top dead centers were established.

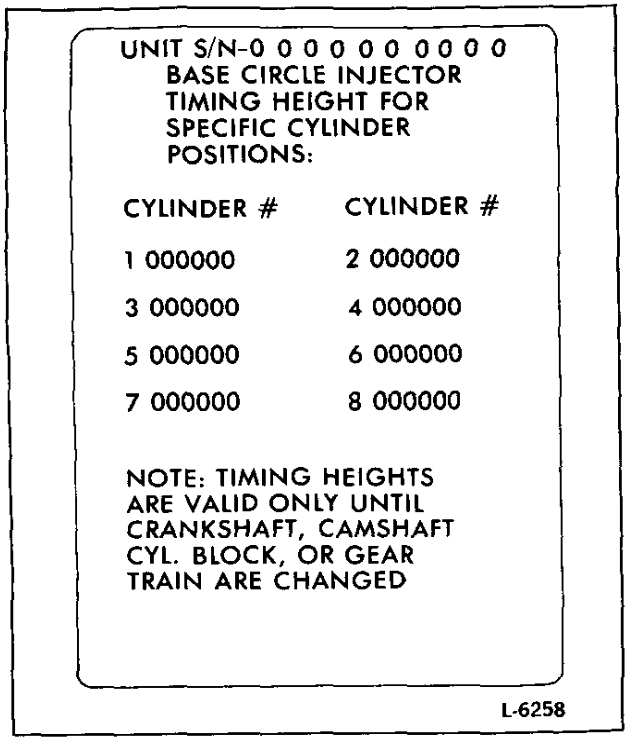


Fig. 3 - Injector Timing Height Label

2. The injector heights were set while their respective pistons were at T.D.C.

3. The base circle injector heights were measured and recorded on a new timing label (to be attached to the left rocker cover).

Remove Timing Pin and Guide

1. Remove tool J 29139 (Timing Pin and Guide) and secure the dust cover in place.

2. Reconnect the battery.

3. Refer to Section 14 and complete the engine tune-up.

INJECTOR RACK CONTROL ADJUSTMENT

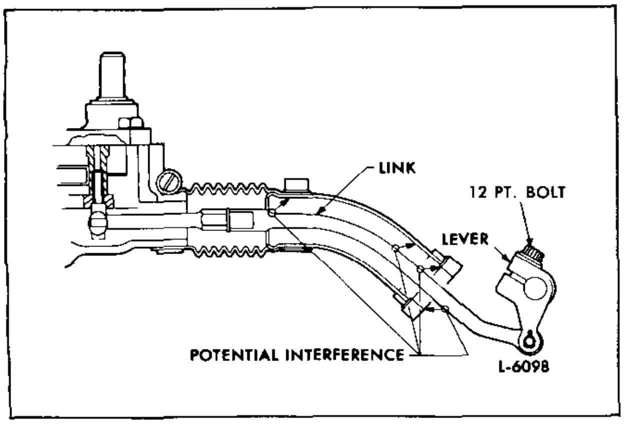


Fig. 1 - Check Points for Interference

Rack Setting

1. Loosen the 12-point clamp bolts in the left and right shaft control levers (Fig. 1).

2. Check to determine that the hex head set screw in No. 1 and No. 2 (Cylinder Position) rack control lever has been correctly installed. If not, tighten it securely. This lever is not adjustable. The set screw must be bottomed (Fig. 2).

3. Rotate the control shaft until the No. 1 injector is in the full-fuel position. Using injector rack control pin J 29523, provide a light spring load on the control shaft to hold the No. 1 injector in the full-fuel position. Loosen the adjusting screws in the three remaining levers on the left bank as required to insure that only the No. 1 injector is at full fuel (Fig. 3).

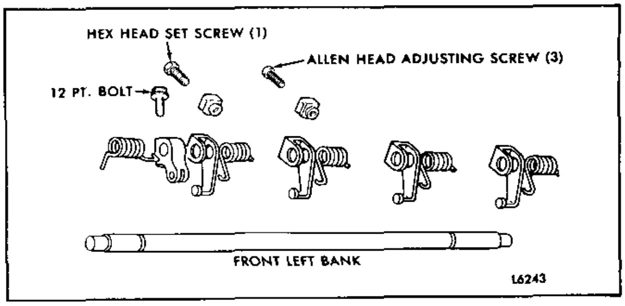


Fig. 2 - Injector Rack Control (Left Bank)

4. Adjust the injectors by tightening the No. 3 rack control lever set screw until a zero lash condition has been obtained between the injector rack and the injector rack control lever. Recheck the No. 1 injector to ensure a zero lash condition has been maintained between the injector rack and the injector rack control lever. If the zero lash condition has been inadvertently lost, back off the adjusting screw on No. 3 injector rack control lever and retighten it slowly. Repeat this procedure on the No. 5 and No. 7 injectors.

> **NOTE:** A screwdriver can be used to check the racks for a zero lash condition.

5. Remove injector rack control pin J 29523.

6. Check the rack control assembly for freedom of movement. The injector rack assembly must return to the no-fuel position without hesitation.

7. Repeat steps 2 through 6 on the right cylinder head for injectors 2, 4, 6 and 8.

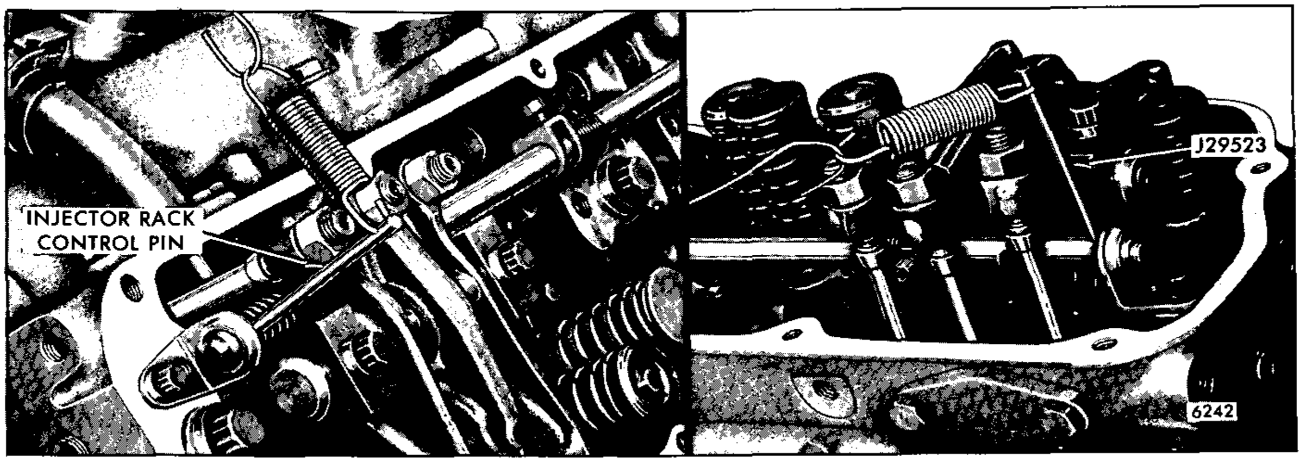


Fig. 3 - Left Bank Front--Right Bank Rear

Governor Check and Setting

1. Remove the governor cover.

2. With the engine stopped and the governor cover removed, place tool J 29646-A between the low-speed spring cap and the high-speed spring plunger. Set the idle gap to 5.5 mm (0.216"), using the gap adjusting screw (Fig. 4).

3. Remove the 3/8" - 24 plug from the side of the governor housing opposite the spring pack.

4. Install a 3/8"-24 bolt (with a minimum of 1-1/2 inches of thread) in the tapped plug hole and screw it in until the gap at low-speed spring cap is reduced to 0.03 - 0.00 mm (0.0015"-0.000")(Fig. 5).

5. Install the governor cover and torque the bolts to 10-12 Nm (7-9 lb-ft).

NOTE: The governor cover should be placed on the governor housing with the pin of the speed control lever projecting into the slot of the differential lever. During cover installation, the roll pin in the fuel shutoff control shaft must be located between the side wall of the governor and the stop pin in the equalizing lever. After the cover has been installed, check operation of speed control and fuel shutoff.

6. Subsequent control adjustments cannot be made correctly unless the governor cover is installed. Check the operation of the fuel shutoff.

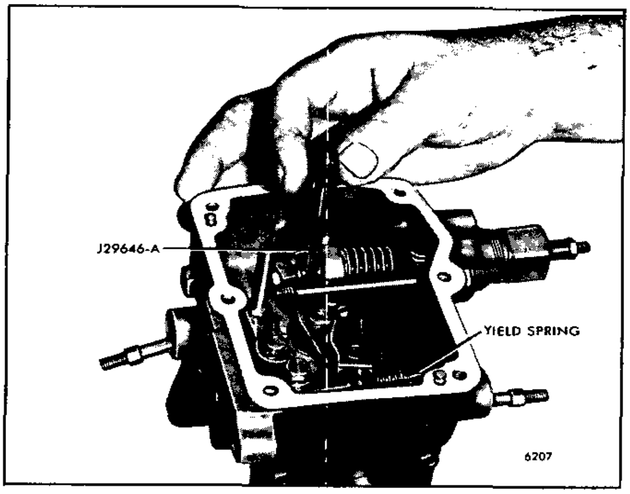


Fig. 4 - Adjusting Governor Gap

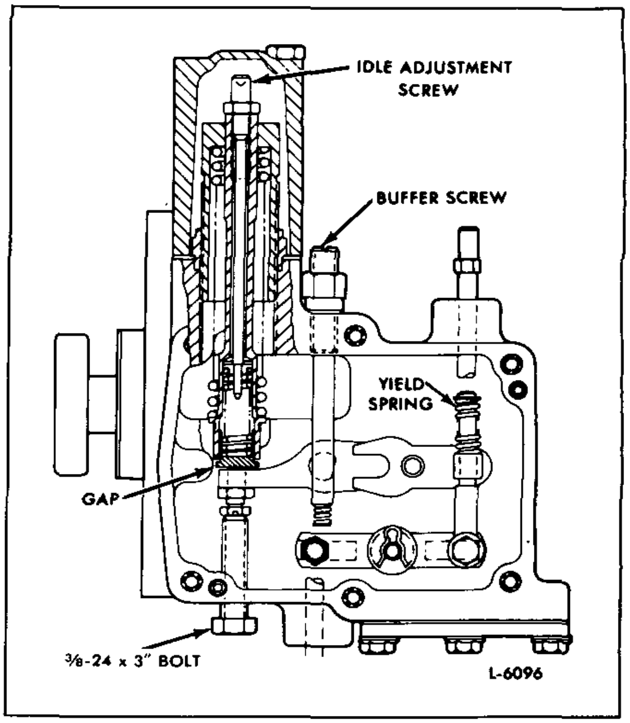


Fig. 5 - Setting Gap at Spring Cap

An electric shutdown solenoid is mounted on the engine governor. The solenoid must be removed from the governor prior to connecting the governor linkage to the rack control shaft or engine overspeed may occur.

This precaution is necessary because the solenoid is designed to hold the fuel shutdown in the *stop* position at all times except when the solenoid is energized. If the injector racks are held in the full-fuel position and connected to the governor while the shutdown is in the *stop* position, the injector will be locked at full rack (maximum fuel).

Governor Control to Injector Rack Connection

1. Secure the governor speed control (throttle) lever in the full-fuel position.

2. Rotate the left bank injector control shaft to hold the injector racks firmly in the full-fuel position with the injector rack control pin J 29523. (Installed at front on the left bank and at rear of the right bank). Refer to Fig. 3.

3. Hold the left shaft control lever (Fig. 1), lightly in direction toward the governor.

4. Carefully tighten the 12 point bolt in the left shaft control lever.

5. Release only the governor speed control lever. Move the speed control lever to idle and back to the full-fuel position. A spongy action indicating yield spring action near the full-fuel position must not be felt at the speed control lever. The speed control lever should not return from the full position more than 1/16". If there is more than a 1/16" movement at the speed control lever, racks must be reset to the governor.

6. Remove the injector rack control pin, J 29523.

7. Move the governor speed control lever to idle and back to the full-fuel position. Check the injector racks for a full-fuel position. If there is injector rack movement, then repeat steps one through seven to correct.

8. Repeat steps one through seven on the right cylinder head.

> **NOTE:** If a bind is present, then check to see if the governor fuel rods are free of any interference with the cylinder head or the tubes (Fig. 1). Also, check the locknut on the governor fuel rods to insure it is tight.

9. Move the governor speed control lever to idle and back to the full-fuel position.

10. Recheck each injector rack in the left and right cylinder heads. If there is movement of injector racks, loosen the left or right lever bolt and repeat steps one through seven.

11. Perform the governor shutoff lever check by holding the lever in the stop position and check that the injectors are in the no-fuel position.

12. Remove the long 3/8" - 24 x 3" bolt and install the 3/8" - 24 plug.

13. Install the rocker covers, breathers, etc.

14. Install the solenoid.

At this point in the Tune-Up procedure, the injector rack adjustments are complete. Continue to Section 14.3.2 for the procedures of the governor adjustment.

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

The limiting speed mechanical governor is centrally located in the upper front section of the engine assembly and is driven by the camshaft gear at a speed of 1.923 times crankshaft speed. The engine fuel supply pump is mounted on the rear of the governor and is driven by the governor drive shaft through an in-line coupling.

Prior to starting the engine for governor adjustment, determine that the following assembly and/or adjustment procedures have been completed in conformity with current engine specifications.

1. Intake and exhaust valve clearances set.

2. Injectors timed.

3. Injector rack control mechanism adjusted.

4. Fuel shut-off operational.

Initial Idle Adjustment (Governor Overhaul)

1. Remove the two 5/16"-18 high-speed spring retainer cover bolts and remove the cover.

2. Back out the buffer screw until 15 mm (5/8") of its threads are beyond the locknut.

3. Loosen the idle-speed adjusting screw (1/4"-28) locknut and adjust the idle screw until it protrudes approximately 8.75 mm (11/32") beyond the locknut (Fig. 1).

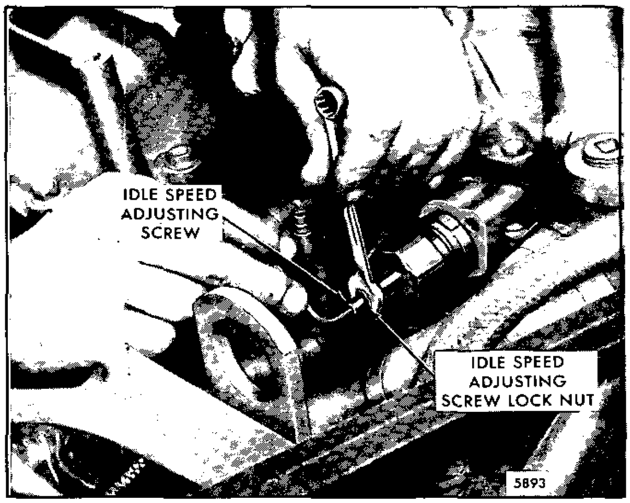


Fig. 1 - Adjusting Engine Idle Speed

4. Loosen the high-speed spring locknut and set the high-speed adjusting nut to 41.4 mm (1-5/8"). Refer to Fig. 2.

> **CAUTION:** Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the *stop* position or the solenoid is deenergized. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.

5. Start the engine.

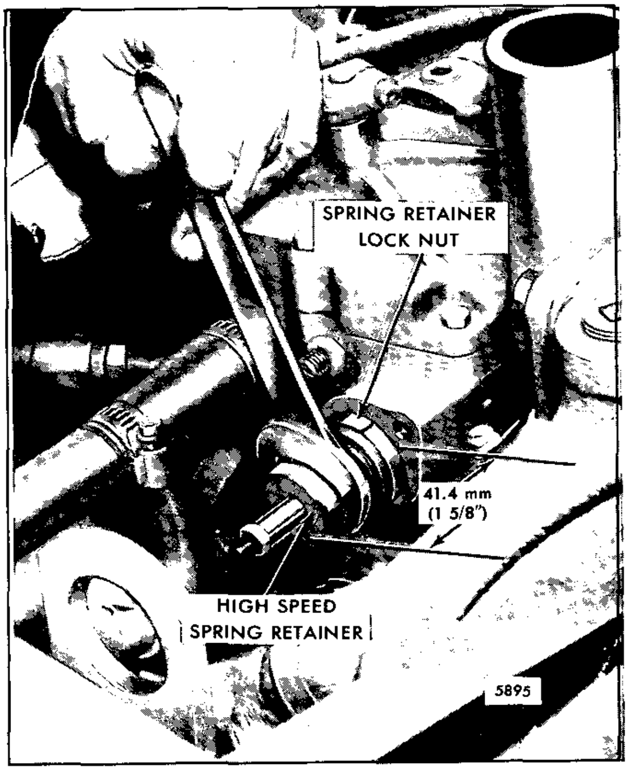


Fig. 2 - Adjusting Maximum No-Load Engine Speed

ALL 8.2 ENGINES (N & T) WITH LIMITING SPEED GOVERNOR	RPM	
RATED SPEED	3000	2800
NO LOAD SPEED	3200 ± 50	3000 ±50

6. Adjust the idle speed to 700 rpm and tighten the locknut.

7. Stop the engine.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory, however, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed, set the maximum no-load speed, as outlined below.

After Governor Overhaul - Replacement Preliminary Governor Speed Adjustment

1. Set the high-speed adjusting nut at 41.4 mm (1 5/8") - (Fig. 2).

2. Back out the buffer screw to avoid contact with the equalizing lever.

3. Start the engine and increase the speed slowly by rotating the speed control lever counterclockwise.

4. If the engine RPM's exceed the specified no-load speed before the speed control lever reaches the end of its travel, back off the high-speed spring retainer (Fig. 2) as required. The recommended no-load speed setting is 3200 RPM for 3000 RPM and 3000 RPM for 2800 RPM rated engines.

> **CAUTION:** No-load speed may be obtained with only half of the speed control lever rotation.

Tune-Up Procedure Final Governor Speed Adjustment or Check

1. Start the engine and bring it up to operating temperature. Stop the engine.

2. Back out the buffer screw.

3. Attach an accurate reading tachometer.

4. Start the engine and increase the speed slowly by rotating the speed control lever counterclockwise.

5. If the engine speed is not within the recommended speed range (see Chart), turn the high-speed spring retainer (Fig. 2), until the engine is operating at the recommended no-load speed.

6. Tighten the locknut on the spring reatiner.

Idle Speed Adjustment (Tune-Up)

With the maximum no-load speed properly set, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the equalizing lever, turn the idle speed adjusting screw (Fig. 1) until the engine idles at the recommended idle speed of 700 rpm.

2. Hold the idle screw and tighten the locknut.

3. Increase the engine speed the to 1500/2000 rpm, close the throttle and recheck the idle speed.

4. Install the high-speed spring retainer cover. Install two 5/16"-18 x 3-1/2" cover bolts and tighten them.

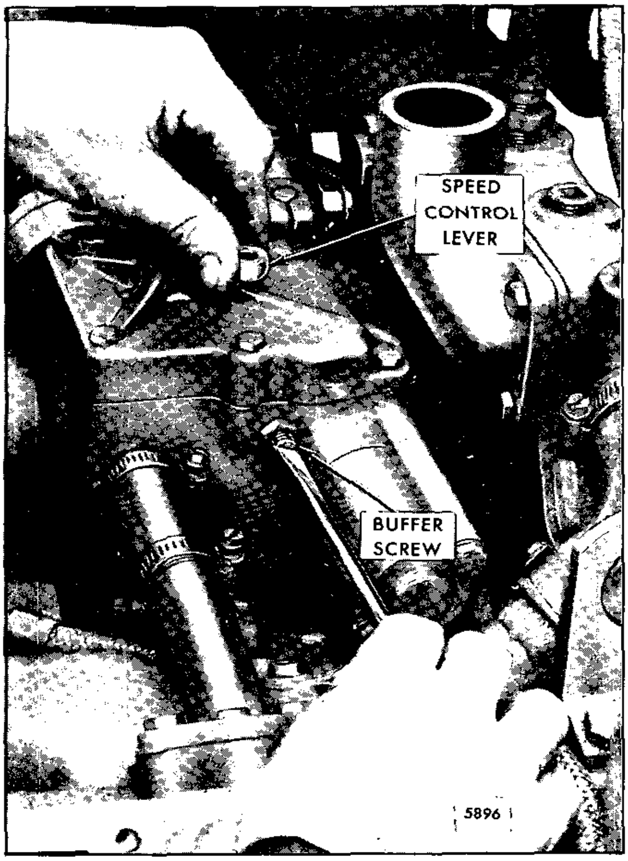


Fig. 3 - Adjusting Buffer Screw

Buffer Screw Adjustment

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at idle speed and normal operating temperature, turn the buffer screw in (Fig. 3) so that it contacts the equalizer lever as lightly as possible and still eliminates engine roll. Do not increase the engine idle speed with the buffer screw more than 15 RPM.

2. Recheck the maximum no-load speed. If the no-load speed is greater than 3300 RPM for 3000 RPM rated speed engines or 3100 RPM for 2800 RPM rated speed engines, back off the buffer screw, as required, to reduce the speed to the above specifications.

3. Hold the buffer screw and tighten the 3/8"-24 locknut.

4. Check the operation of the stop lever while running at no-load rpm with the throttle in "Run" position. If the engine does not shut off, back out the buffer screw until it does.

The Tune-Up is now complete and the engine can be returned to service.

SECTION 15

PREVENTIVE MAINTENANCE - TROUBLE SHOOTING

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best preformance from a Detroit Diesel engine. The intervals indicated on the Chart are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

Maintenance functions 1 through 5 should be performed daily. Items 6 through 10 should be performed at 6,000 mile intervals. Item 11 should be performed at 12,000 mile intervals. Items 12 through 23 should be performed at the intervals (whichever comes first, the time or mileage increments) as shown in the Chart. Items 24 and 25 should be performed annually.

Instructions on the pages following the Chart describe the maintenance function involved.

LUBRICATION AND PREVENTIVE MAINTENANCE CHART

DAILY	
1. Lubricating Oil	I
2. Fuel Tanks	I
3. Fuel Lines	I
4. Cooling System	I
5. Turbocharger	I

6,000 MILE INTERVALS	
6. Lubricating Oil (See Note Below)	R*
7. Lubricating Oil Filters	R*
8. Air System	I
9. Drive Belts	I
10. Air Compressor/Vacuum Pump	I

12,000 MILE INTERVALS	
11. Fuel Filters	R

6 MONTHS OR 10,000 MILE INTERVALS	Months	6	12	18	24	30	36	42	48	54.	60
	Mile In Thousands	10	20	30	40	50	60	70	80	90	100
12. Air Cleaner			I		I		I		I		I
13. Starting Motor		I	I	I	I	I	I	I	I	I	I
14. Fuel Tanks			I		I		I		I		I
15. Cooling System			I		I		I		I		I
16. Exhaust System			I		I		I		I		I
17. Air Compressor			I		I		I		I		I
18. Radiator			I		I		I		I		I
19. Oil Pressure			I		I		I		I		I
20. Governor						I					I
21. Fuel Injectors & Valve Clearance						I					I
22. Alternator (Battery-Charging)								I			
23. Engine & Transmission Mounts								I			

ANNUALLY	
24. Thermostats & Seals	I
25. Fan	I

I = Inspect, Correct or Replace If Necessary
R = Replace
* = Check Level Daily. Replace Oil and Filters Every 6,000 Miles or 200 Hours.

Item 1 - Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately ten minutes to allow the oil to drain back to the oil pan. Add the proper grade oil (refer to Section 13.3) as required to maintain the correct level on the dipstick.

> **NOTE:** Oil may be blown out through the crankcase breather if the crankcase is overfilled or engine could overspeed.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

Item 2 - Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with *Fuel Specifications* in Section 13.3. Open the drain at the bottom of the fuel tank every other month to drain off any water or sediment.

Every 12 months or 20,000 miles tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts, if necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of mircobiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

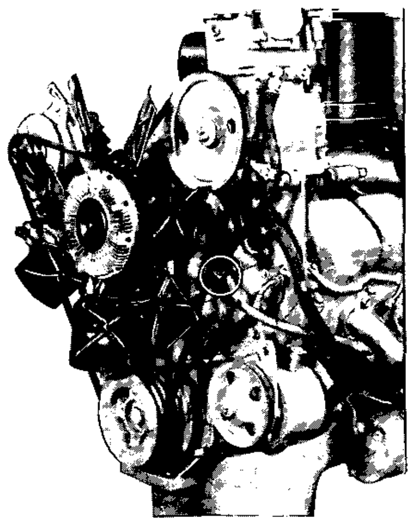
Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10% by volume).

Marine units in storage are particularly susceptible to mircobe growth. The mircobes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

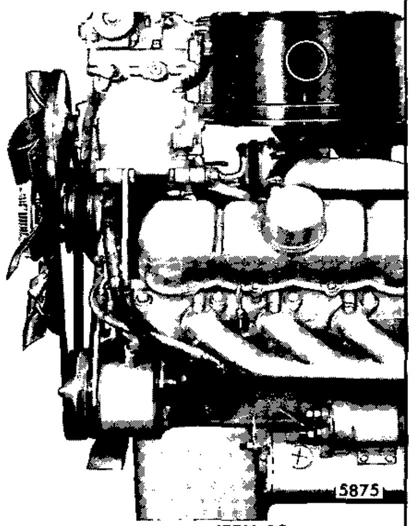
Microbe growth can be eliminated through the use of commerically available biocides. There are two basic types on the market.

1. The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

ITEM 1, 6, 7



ITEM 4



ITEM 12

2. Diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax or equilvalent, treats *the fuel* itself and therefore the entire fuel system.

Marine units, or any other application, going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 - Fuel Lines

Make a visual check for fuel leaks at the cross-over lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

Item 4 - Cooling System

Before starting the engine each day, always check the coolant level. Make sure the coolant covers the radiator tubes. Add coolant as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

Item 5 - Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check for restrictions to air flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.

Item 6 - Lubricating Oil

Change the initial lubricating oil at approximately 6,000 mile intervals. The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the oil sample analysis) until the most practical oil change period has been determined. Select the proper grade of oil in accordance with the instructions given in *Lubrication Specifications* in Section 13.3.

Item 7 - Lubricating Oil Filters

Change the lubricating oil filters when the engine oil is changed. Any deviation, such as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and the used filter elements to determine if such practice is practical for proper protection of the engine.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

Item 8 - Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.

Item 9 - Drive Belts

New drive belts stretch during the first few hours of operation. Run the engine 30 *seconds*, to seat the belts and readjust the tension. Then, check the belts and retighten fan drive, pump drive and battery-charging alternator drive belts after 250 miles of operation. Thereafter, check the tension of the drive belts at the intervals shown in the Chart. Too tight a belt is destructive to the bearings of the driven part, a loose belt will slip.

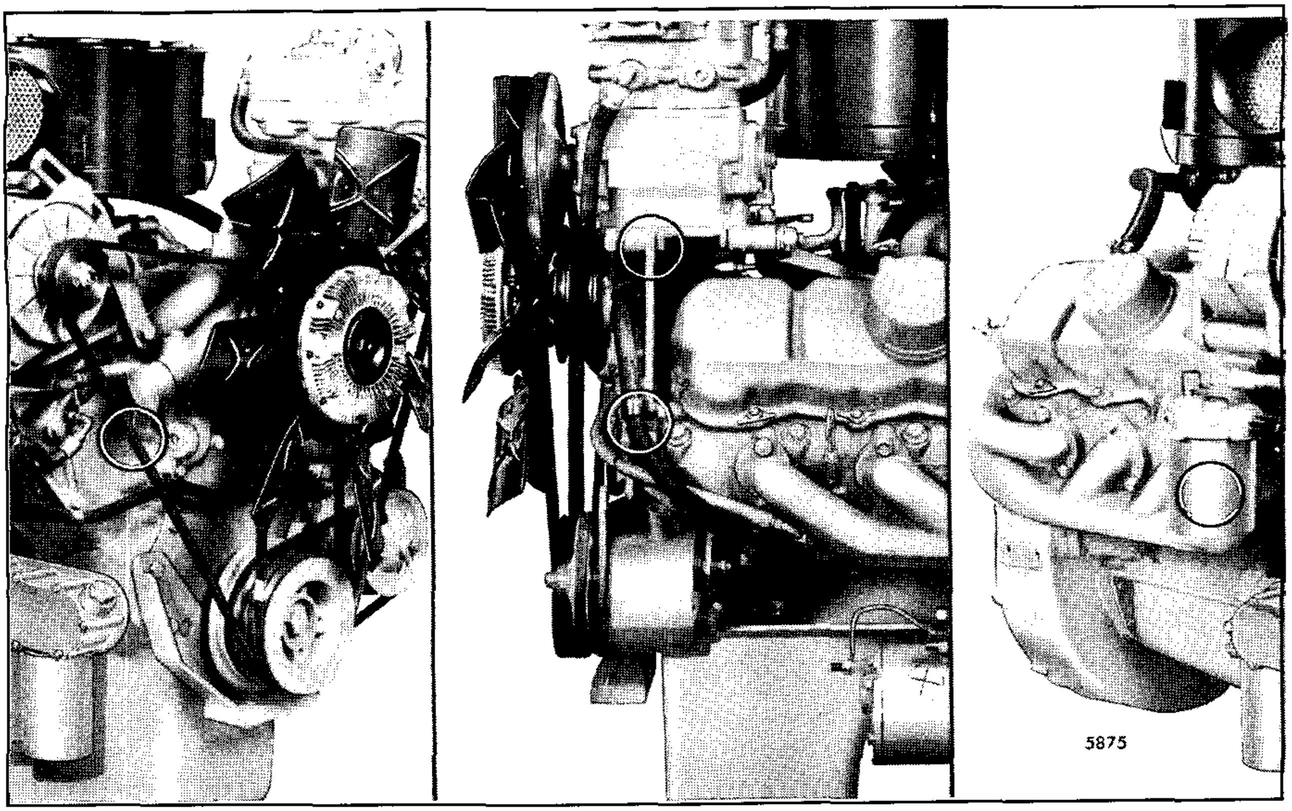
Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .81 mm (.032") of their specified center distances.

Adjust the belt tension using belt tension gage J 23600-B or equivalent. Adjust the belt tension as outlined per belt tension Chart.

Item 10 - Air Compressor/Vacuum Pump

Remove and clean air compressor air intake parts. To clean either the hair or polyurethane type element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until dirt free. Then, dip in lubricating oil and squeeze dry before placing the element back in the air strainer.

For replacement of the air strainer element, contact the air compressor manufacturer/dealer.



Item 9 Items 10, 17 Item 11

Alternator Drives		Fan/Accy. Drives
One 1/2" Belt	Two 1/2" Belt	One 1/2" Belt
60 ± 10	45 ± 5	90 ± 10

BELT TENSION CHART (lbs/belt)

Inspect the vacuum pump oil supply, oil return and vacuum lines and replace, if necessary.

Item 11 - Fuel Filters

Install new strainer and filter at the intervals shown in the chart, or when plugging is indicated.

A method of determining when elements are plugged to the extent that they should be changed is based on the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury. Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury at normal operating speeds.

Item 12 - Air Cleaner

Inspect and service the air cleaner element every 20,000 miles, or more often if the engine is operated under severe dust conditions. Check the gaskets for deterioration and replace, if necessary. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

Under no engine operating conditions should the air inlet restriction exceed 20 inches of water. A clogged air cleaner element will cause excessive intake retriction and a reduced air supply to the engine.

Item 13 - Starting Motor

Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers, or oil tubes sealed with pipe plugs) should be lubricated at the intervals shown on the Chart. Add 8 to 10 drops of oil, of the same grade as used in the engine, to hinge cap oilers; if sealed tubes are provided, remove the pipe plugs add oil

and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups, if necessary. However, some starting motors do not require lubrication except during overhaul.

Item 14 - Fuel Tanks

Check all fuel tank mountings and brackets and tighten or replace as necessary. At the same time, check the seal in the fuel tank cap, the breather hole in the cap, and the condition of the cross-over fuel line. Repair or replace the parts as necessary.

Item 15 - Cooling System

Check the cooling system hoses for deterioration or damage and replace, if necessary. Check all of the hose clamps to make sure they are tight and properly seated on the hoses.

Item 16 - Exhaust System

Check the exhaust manifold retaining bolts, exhaust flange clamp and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.

Item 17 - Air Compressor

Check the air compressor mounting bolts and tighten, if necessary. Check the drive belts for proper tension.

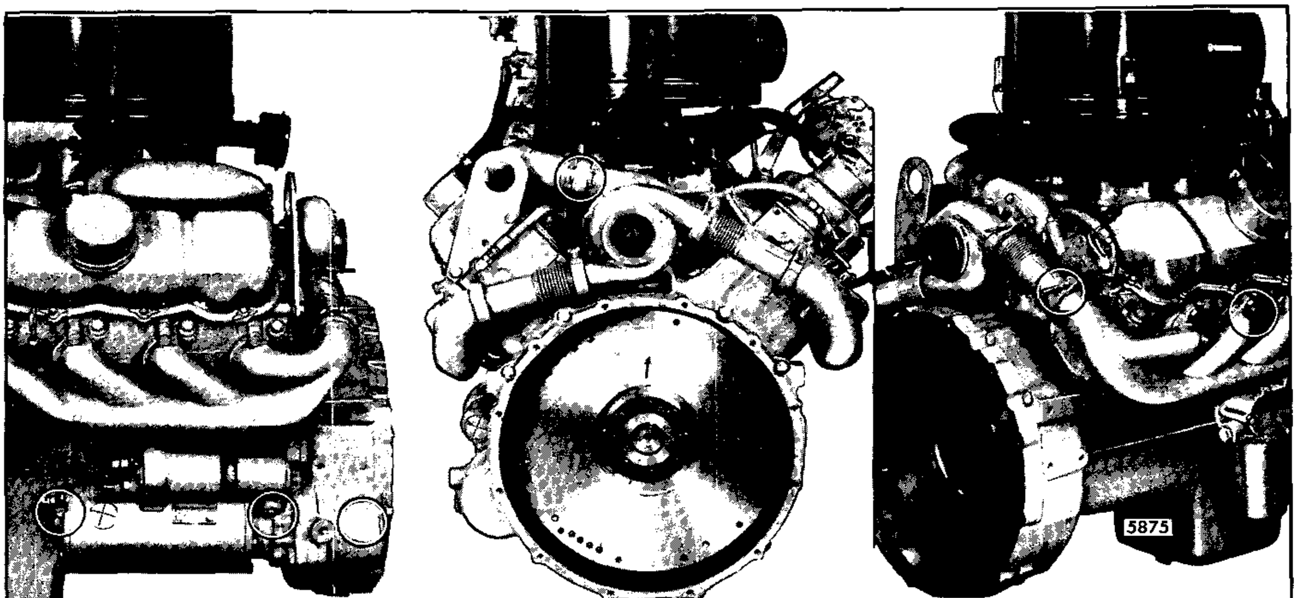
tem 18 - Radiator

nspect the exterior of the radiator core and steam clean it, if necessary.

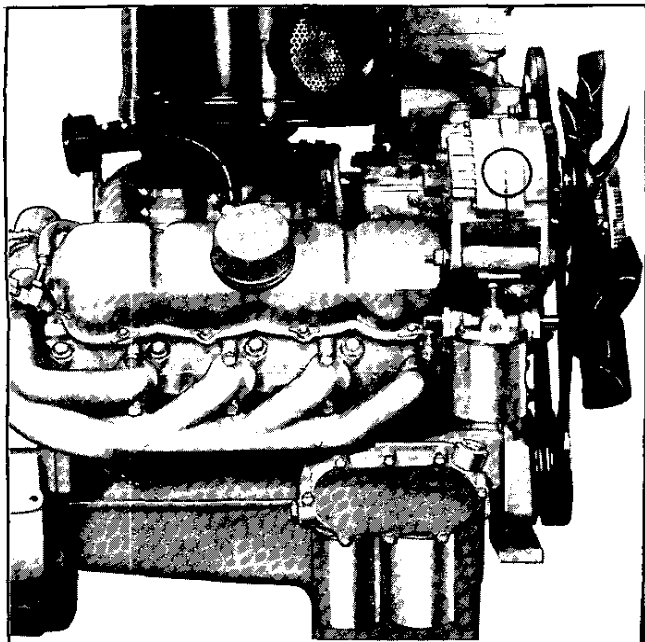
> **NOTE:** Never use fuel oil, kerosene or petroleum base solvents for cleaning since they may leave an oil film on the radiator fins.

Item 19 - Oil Pressure

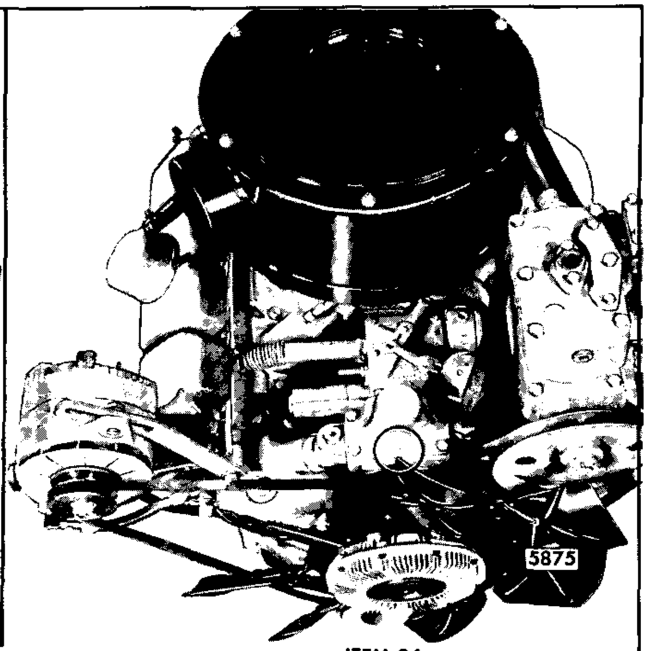
Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded at the interval indicated.



ITEM 13 ITEM 8 ITEM 16



ITEM 22



ITEM 24

Item 20 - Governor

Check and record the engine idle speed and no-load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified and may result in engine stalling.

A no-load speed higher than recommended will result in a full-load speed higher than rated and higher than the speed at which the engine was certified.

Item 21 - Fuel Injectors

Check the injector timing and intake and exhaust valve clearances. The proper adjustment of the injectors is of primary importance to emission control.

Item 22 - Alternator (Battery-Charging)

Check the alternator mounting bracket bolt torques and tighten if necessary. Check drive belts for proper belt tension.

Item 23 - Engine and Transmission Mounts

Check the engine and transmission mounting bolt torques and the condition of the mounting pads. Tighten and repair, as necessary.

Item 24 - Thermostats

Check the thermostats (preferably at the time the cooling system is prepared for winter operation).

Item 25 - Fan

Check the cooling fan mounting bolt torques and tighten, if necessary. In installations where a viscous fan clutch is used, inspect and replace, if necessary. Tighten viscous fan clutch mounting bolts, if necessary.

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air or other causes.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine with the rocker cover removed.

2. Position and secure the governor control lever in the idle position.

3. Using flooding bar J 29522, push the injector control levers into full fuel one at a time. Hold the respective injector in the full fuel position for 3 to 6 seconds and observe the performance of the engine.

4. If the cylinder that is being "flooded" with fuel is firing, there will be a noticeable and quick increase in RPM. A "dead" cylinder will show little or no change in RPM.

> **CAUTION:** Do not "short out" the injector because the push rod may leave the engine and cause injury.

5. If the cylinder is still misfiring, check the following:

a. Check individual rack lever settings compared to others when at full fuel position. Adjust if necessary.

b. Check the injector timing (refer to Section 14.2).

c. Install a new injector.

d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

Cylinder Leakage Test

Loss of compression in diesel engines derives from a variety of sources, including worn or broken piston rings, holes in pistons, leaky valves, scored or worn cylinder walls. The detection, and elimination of the cause or causes of cylinder pressure losses are vital to engine life and efficient operation.

Before the cylinder leakage test is run, the engine should be operated to warm it up. Next, shut the engine off and secure the governor stop lever in a no-fuel postion. Remove the air cleaners crankcase breather hose, and radiator cap. As air pressure is applied externally to a cylinder under test, any leak in the cylinder will become traceable elsewhere in the engine. The cylinder leakage tester will not indicate the condition of oil control rings, but it will indicate the condition of compression rings. Illustration of cylinder leakage tester shown in Fig. 1.

1. To check for cylinder leakage run the engine until it warms up. A cold engine will leak a lot worse because the compression rings depend partially on a hydraulic seal.

2. Drain the cylinder head fuel galleries. Refer to Section 2.1.1.

3. Remove the rocker covers, crankcase breather hose, air cleaner, and radiator cap.

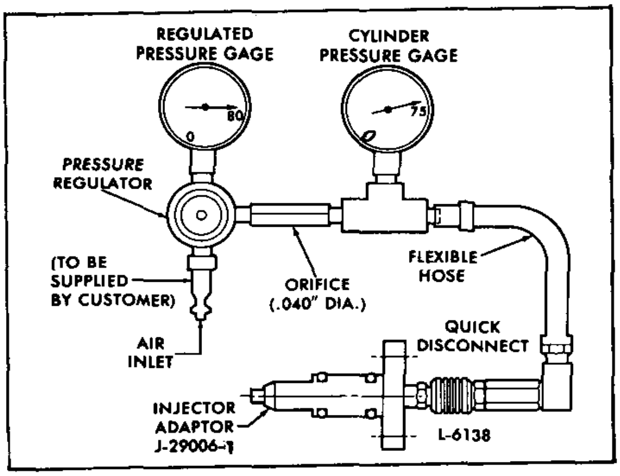


Fig. 1 - Cylinder Leakage Tester J 29006

4. Secure the governor stop lever in a no-fuel position. Then rotate the crankshaft using a suitable barring tool until the injector cam follower descends 3.6 mm (.141") on the cylinder to be tested. Now the piston in that cylinder has been positioned at TDC.

5. Remove the injector and valve rocker arm assembly.

6. Remove the injector and insert Tool J 29006-1 cylinder leakage adaptor into the hole tube. Using the injector hold down bolts, secure the adaptor in place and tighten the hold down bolts to 10-12 Nm (7-9 lb-ft) torque.

NOTE: Do not exceed the torque specifications.

7. Connect a suitable air source to the regulator "IN" port.

NOTE: Air supply for the tester should be clean and free from oil, moisture an/or foreign particles that might be injected into the regulator or orifice chamber can cause improper operation and erroneous readings. Desired regulator "IN" pressure 689-861 kPa (100-125 psi) max. 1034 kPa (150 psi).

8. Connect the cylinder leakage adaptor air line to the J 29006 cylinder leakage tester.

9. Slowly adjust regulated air pressure to 552 kPa (80 psi). Observe the crankshaft during this operation. If the crankshaft tends to rotate, the piston was not at TDC. Release air pressure and rotate the crankshaft in a clockwise direction until the piston is at TDC.

NOTE: Piston must be at TDC when performing a cylinder leakage test.

CYLINDER	GAGE READING
1	75
2	
3	
4	
5	
6	
7	
8	

TABLE 1

10. Allow approximately 60 seconds for the air pressure in the cylinder to stabilize. Observe the cylinder pressure gage and record the pressure as indicated in the example in Table 1.

11. Listen for escaping air at the air inlet, crankcase breather hose, exhaust outlet and look for air bubbles in the radiator coolant (see Trouble Shooting Chart).

12. A good cylinder should maintain 386 kPa (56 psi) or more pressure on the cylinder pressure gage. Cylinders must maintain a minimum of at least 331 kPa (48 psi). Any cylinder that does not maintain a minimum of 331 kPa (48 psi) must be investigated to see where leakage exists. If a cylinder is found to have excessive leakage, bar the crankshaft over two revolutions and recheck the cylinder.

13. Repeat the procedure on the other cylinders.

NOTE: Due to standard engine clearances and normal wear, no cylinder is expected to maintain 552/552 kPa (80/80 psi).

Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of 38 liters (ten gallons) of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

A primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 under *Trouble Shooting*.

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder walls into the crankcase, most of which is clean air. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder head is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, scuffed or scored cylinder block bore and piston, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder head. Check the readings obtained at various engine speeds with the *Engine Operating Conditions* in Section 13.2.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing (non-turbocharged engines) or the compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point (non-turbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner, is the actual restriction caused by the air cleaner.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in Section 13.2.

PROPER USE OF MANOMETER

PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 2

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

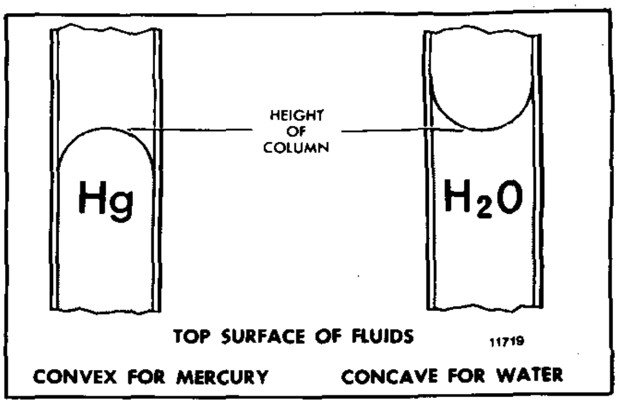
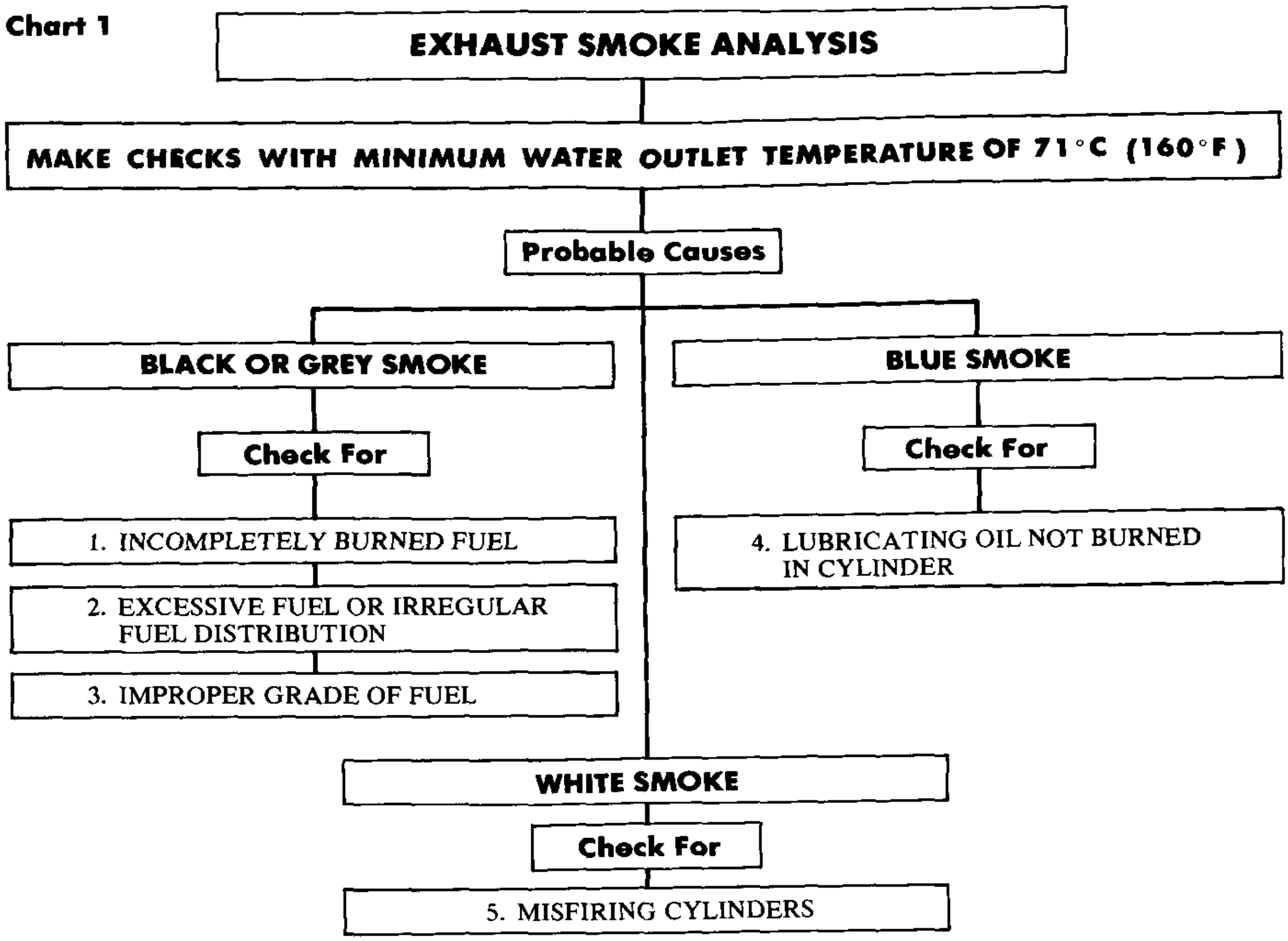


Fig. 2 - Comparison of Column Height for Mercury and Water Manometers

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 2 to convert the manometer reading into other units of measurement.

Chart 1



SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by a clogged air cleaner. Clean the air cleaner.

2. Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

3. Check for use of an improper grade of fuel. Refer to *Fuel Oil Specifications* in Section 13.3.

4. Check for internal lubricating oil leaks.

5. Check for faulty injectors and replace as necessary.

Check for low compression and consult the *Hard Starting* chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Oil Specifications* in Section 13.3.

Chart 2

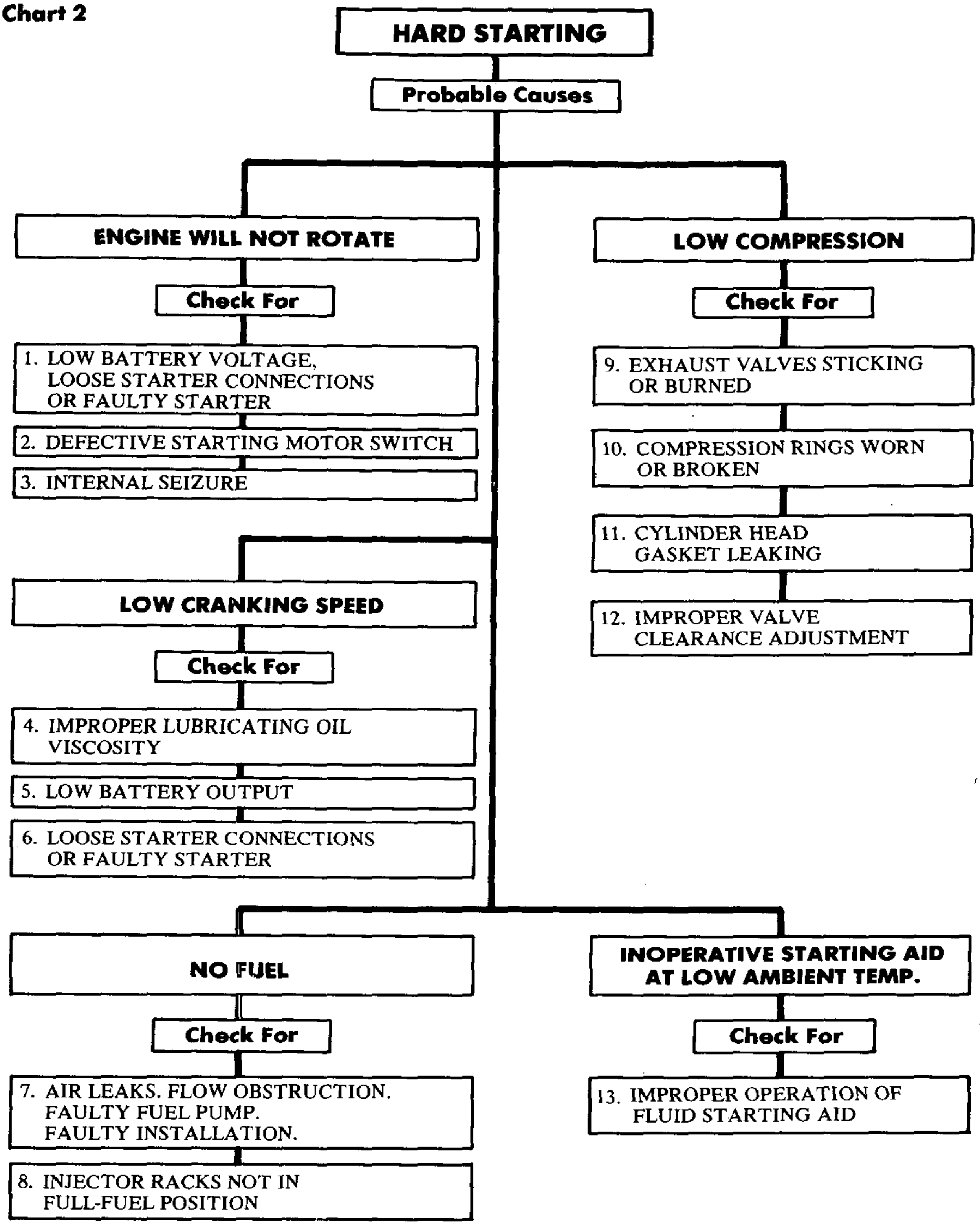

HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS. FLOW OBSTRUCTION. FAULTY FUEL PUMP. FAULTY INSTALLATION.
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
13. IMPROPER OPERATION OF FLUID STARTING AID

Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least two complete revolutions. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubricating Oil Specifications* in Section 13.3 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

Replace terminals that are damaged or corroded.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the valves.

10. Inspect the cylinder bores for scratches, gouges, etc. Remove the pistons and overhaul the defective cylinder bores and piston assemblies.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the valve clearance.

13. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

Chart 3

ABNORMAL ENGINE OPERATION

Probable Causes

UNEVEN RUNNING OR FREQUENT STALLING

Check For

1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
6. BROKEN VALVE SPRINGS (CYLINDER MISFIRE)

LACK OF POWER

Check For

7. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
8. INSUFFICIENT FUEL
9. INSUFFICIENT AIR
10. ENGINE APPLICATION
11. HIGH RETURN FUEL TEMPERATURE
12. HIGH AMBIENT AIR TEMPERATURE
13. HIGH ALTITUDE OPERATION
14. INCORRECT INJECTOR OUTPUT

DETONATION

Check For

15. OIL PICKED UP BY AIR STREAM
16. LOW COOLANT TEMPERATURE
17. FAULTY INJECTORS

Chart 3

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and if the temperature does not reach 77° to 90°C (170° to 195°F) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinder and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

6. Inspect all intake and exhaust valve springs for coil breakage and proper valve lash.

7. Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

8. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

9. Check for damaged or dirty air cleaner and clean, repair or replace damaged parts.

Check for air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

10. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures outlined in the *Owner Operator Handbook*.

11. Refer to Item 13 on Chart 4.

12. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size, for each 6°C (10°F) temperature rise above 32°C (90°F) will occur. Relocate the engine air intake to provide a cooler source of air.

13. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

14. Check injector output. Refer to Section 2.0, Chart 3.

15. Check the oil level, turbo seals and crankcase breathing system.

16. Refer to item 1 of this chart.

17. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

Chart 4

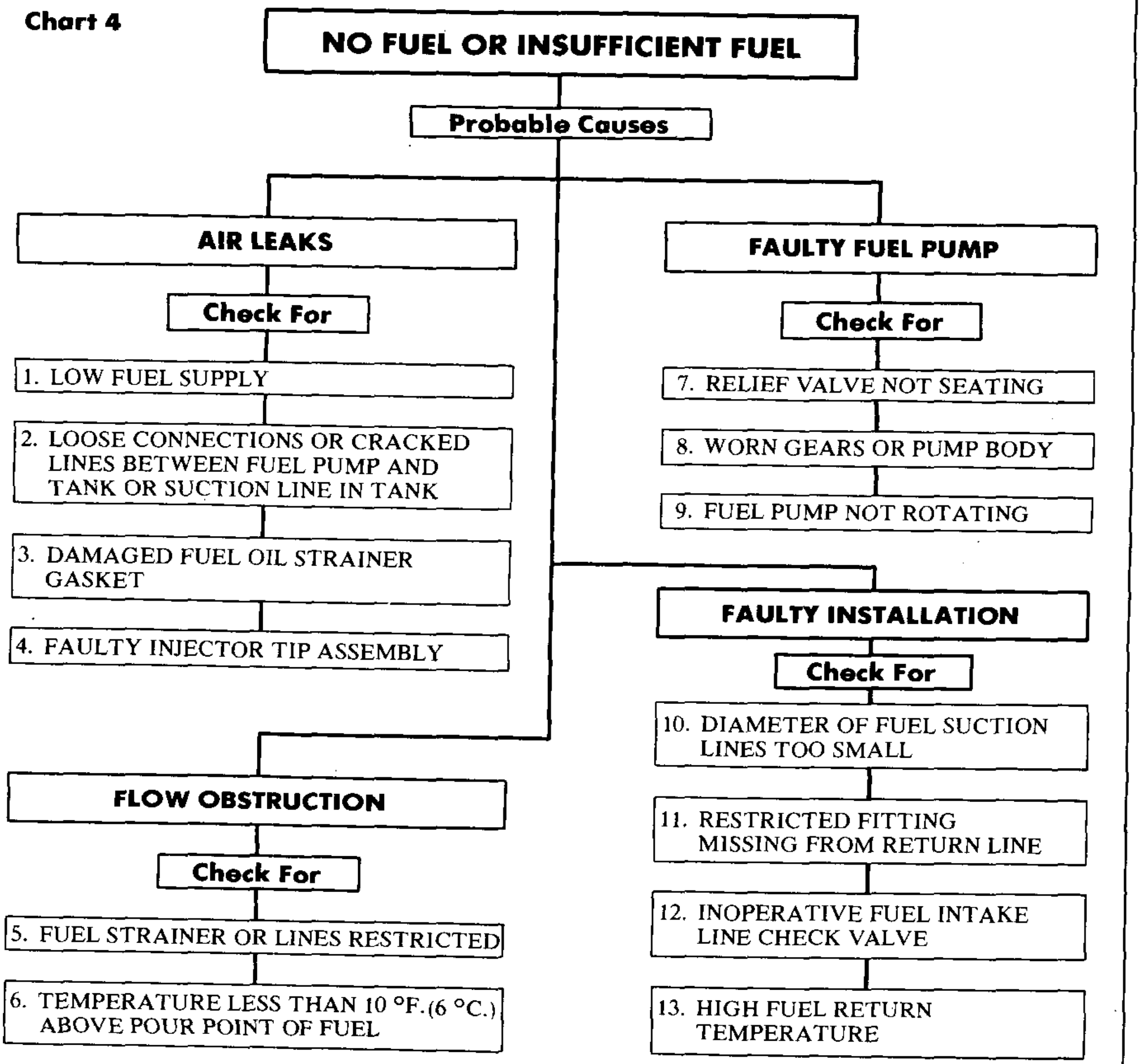

NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F.(6 °C.) ABOVE POUR POINT OF FUEL
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 4

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.

2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.

3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.

4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.

5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary,

6. Consult the *Fuel Oil Specifications* for the recommended grade of fuel.

7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.

8. Replace the gear and shaft assembly or the pump body.

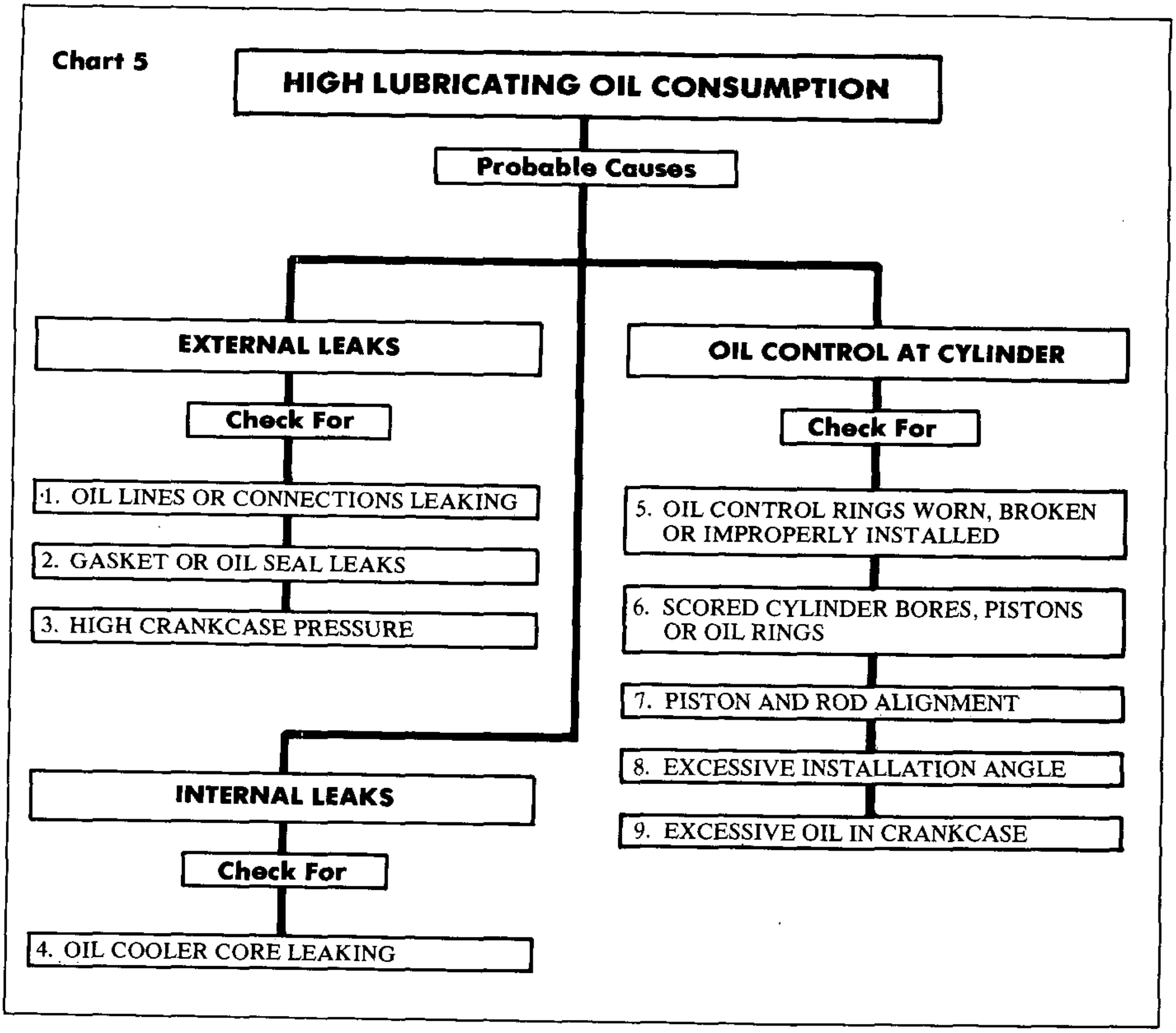
9. Check the condition of the fuel pump drive and replace defective parts.

10. Replace with larger tank-to-engine fuel lines.

11. Install a restricted fitting in the return line.

12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.

13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150 °F (66 °C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.



SUGGESTED REMEDY

1. Tighten connections or replace defective parts.

2. Replace defective gaskets or oil seals.

3. Refer to the *Excessive Crankcase Pressure* chart.

4. Refer to the *Abnormal Engine Operation* chart.

Inspect the engine coolant for lubricating oil contamination; if comtaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.

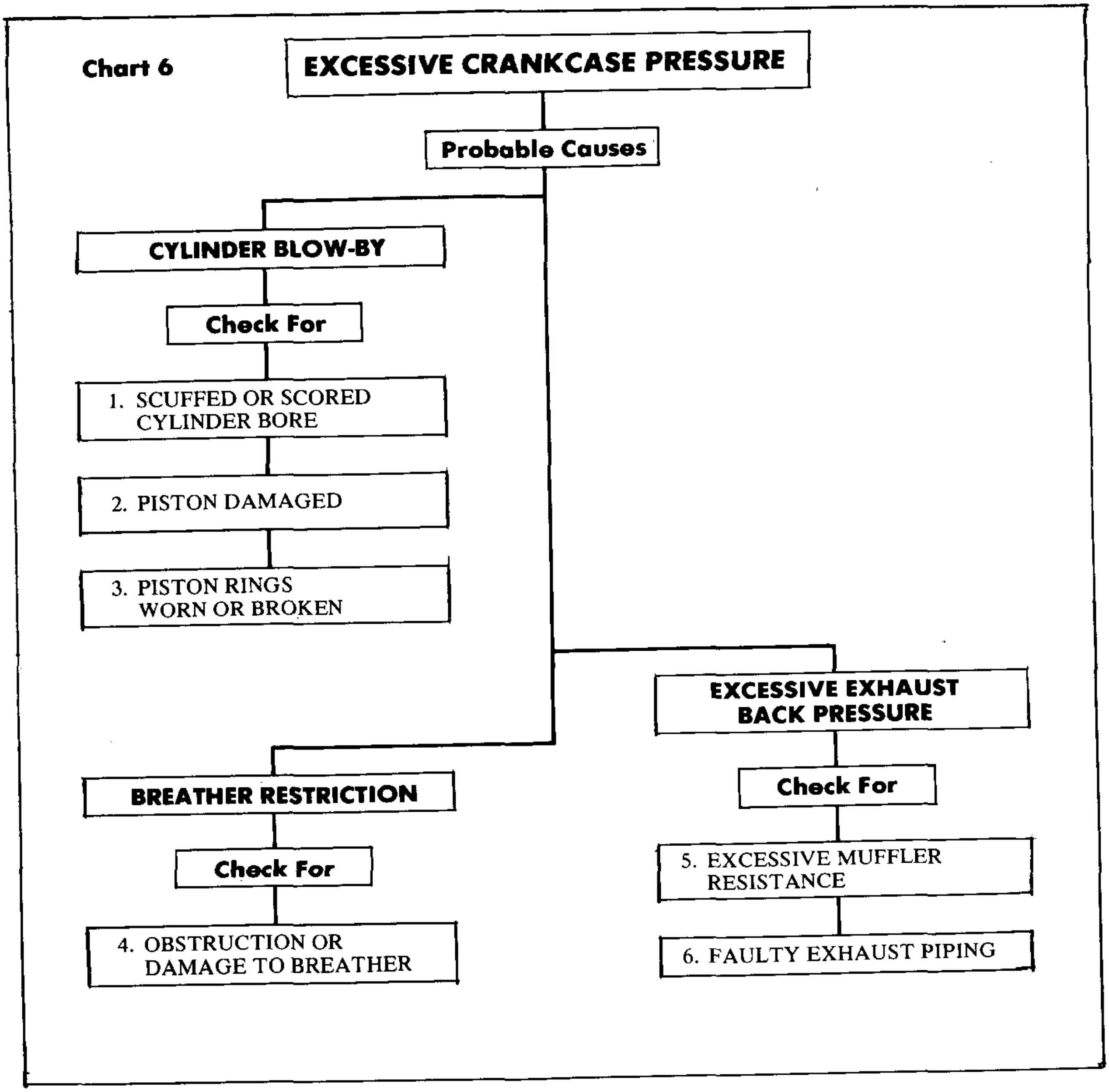
5. Replace the oil control rings.

6. Remove and replace the defective parts.

7. Check the crankshaft thrust bearing for wear. Replace worn and defective parts.

8. Decrease the installation angle.

9. Fill the crankcase to the proper level only.



SUGGESTED REMEDY

1. Check cylinder leakage and if a cylinder has excessive leakage, remove the cylinder head and piston assembly and inspect for scuffing or scoring in the cylinder block bore.

2. Inspect the piston and replace damaged parts.

3. Install new piston rings.

4. Clean and repair or replace the breather assembly.

5. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.

6. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

Chart 7

LOW OIL PRESSURE

MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160 °F. (71 °C.)

Probable Causes

LUBRICATING OIL

Check For

1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY

POOR CIRCULATION

Check For

3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY PLUGS MISSING

PRESSURE GAGE

Check For

8. FAULTY GAGE
9. GAGE LINE OBSTRUCTION
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY

OIL PUMP

Check For

12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubricating Oil Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring. A leak here will cause lubricating oil dilution. Refer to Fuel Leak Detection in Section 2.0.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the by-pass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

11. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubricating Oil Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the flange and replace the gasket.

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE

Probable Causes

ABOVE NORMAL

Check For

1. INSUFFICIENT HEAT TRANSFER
2. POOR CIRCULATION

BELOW NORMAL

Check For

3. IMPROPER CIRCULATION
4. EXCESSIVE LEAKAGE AT THERMOSTAT SEAL

SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat; replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for 30 days or less, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   NOTE: Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1.

5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer's recommendations.

6. Clean the outside of the engine (except the electrical system) with fuel oil and dry it with compressed air.

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil and transmission.

EXTENDED STORAGE (more than 30 days)

To prepare an engine for extended storage (more than 30 days) follow this procedure:

1. Drain the cooling system and flush with clean, soft water. Refill with clean, soft water and add a rust inhibitor to the cooling system (refer to *Engine Coolant* in Section 13.3).

2. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.

3. Reinstall the injectors, time them and adjust the exhaust valve clearance.

4. Circulate the coolant by operating the engine until normal operating temperature is reached (See Section 13.2).

5. Stop the engine.

6. Drain the engine crankcase then reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.

7. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260B, Grade 2.

8. Drain the fuel tank. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank (i.e., marine) use a separate portable supply of the recommended fuel.

   NOTE: If engines in vehicles or marine units are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint to 125 gallons of fuel or .010% by volume. Where biological contamination of

fuel may be a problem, add a biocide such a Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and warnings.

9. Drain and disassemble the fuel filter and strainer. Discard the used elements and gaskets. Wash the shells in clean No. 1 diesel fuel or pure kerosene and insert new elements. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene and reinstall on the engine. If spin-on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene and install on the engine.

10. Operate the engine for five minutes to circulate the clean fuel oil throughout the fuel system.

11. Refer to Section 3.1 and service the air cleaner.

12. TURBOCHARGER

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

13. Apply a *non-friction* rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

NOTE: Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

14. Drain the engine cooling system.

15. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.

16. Remove and clean the battery and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32° F or 0° C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

17. Insert heavy paper strips between the pulleys and belts to prevent sticking.

18. Seal all of the openings in the engine, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

19. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

20. Protect the engine with a good weather-resistant tarpaulin and store it under cover, perferably in a dry building which can be heated during the winter months.

Detroit Diesel Allison does not recommend the outdoor storage of engines (or transmission). Nevertheless, DDA recognizes that in some cases outdoor storage may be unavoidable. If units must be kept outdoors, follow the preparation and storage instructions already given. Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

NOTE: *Do not use plastic sheeting for outdoor storage.* Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Reinstall the drain plug. Then, refer to *Lubrication System* in Section 13.1 and fill the crankcase to the proper level, using a pressure lubricator, with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under *Fuel Specifications* (Section 13.3).

7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a solution of water and an ethylene glycol base antifreeze (refer to Section 13.3).

8. Install and connect the battery.

9. Service the air cleaner as outlined in Section 3.1.

10. After all of the preparations have been completed, start the engine.

NOTE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune-up.

Detroit Diesel
Engines

8.2 Liter
Service Manual

Detroit Diesel
Allison